PUBLIC DOCUMENTS
DEPOSITORY ITEM

OCT 7 1987

CLEMSON
LIBRARY

Digitized by the Internet Archive
in 2013

http://archive.org/details/generaltechnical2182inte

United States
Department of
Agriculture

Forest Service

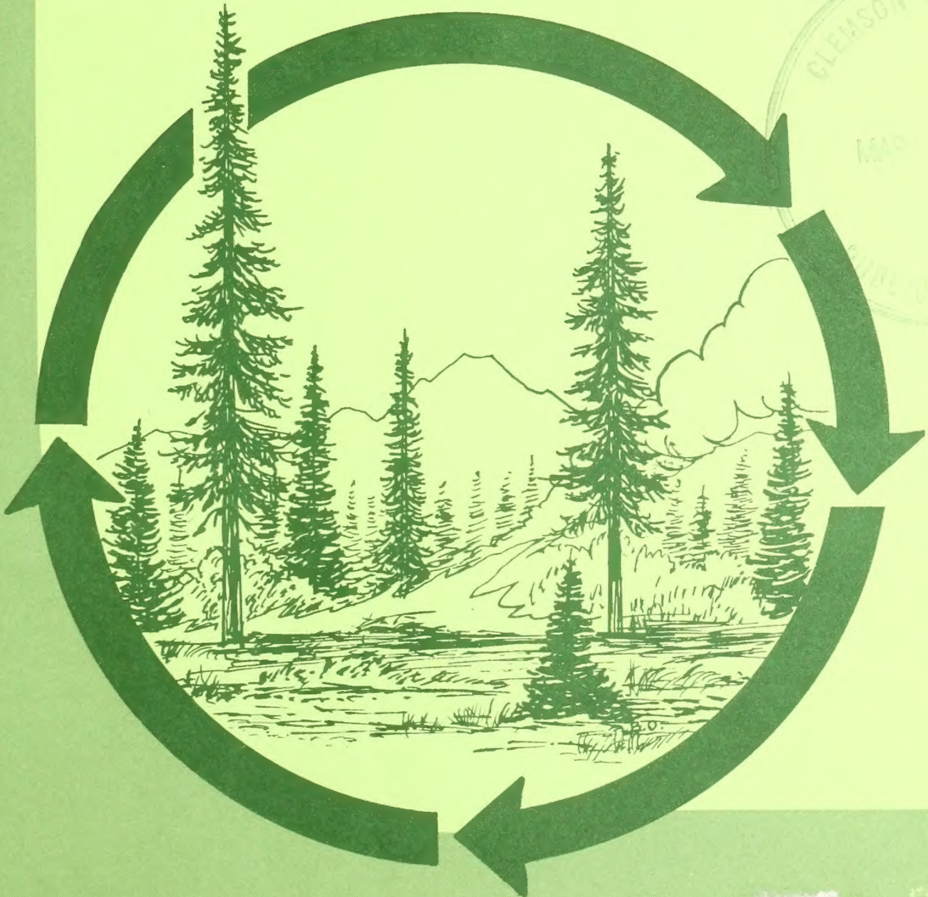
**Intermountain
Research Station**

General Technical
Report INT-218

December 1986

Fire Ecology of the Forest Habitat Types of Central Idaho

**M. F. Crane
William C. Fischer**



CLEMSON UNIVERSITY

THE AUTHORS

MARILYN (MARTI) F. CRANE is a research plant ecologist with Systems for Environmental Management, a nonprofit research foundation in Missoula, MT. Ms. Crane earned a B.A. degree from San Jose State University in 1961 and an M.A. (botany) from the University of Montana in June 1980.

WILLIAM C. FISCHER is a research forester for the Prescribed Fire and Fire Effects research work unit at the Intermountain Research Station's Intermountain Fire Sciences Laboratory, Missoula, MT. He earned his B.S. and B.S.F. degrees from the University of Michigan in 1956. Before coming to the fire lab in 1966 he worked as a forester on the Boise National Forest in central Idaho.

ACKNOWLEDGMENTS

This report is the result of a cooperative endeavor between the Intermountain Research Station's Prescribed Fire and Fire Effects research work unit and several central Idaho National Forests of the USDA Forest Service Intermountain Region (Region 4). The following individuals were especially supportive of this project: Marvin L. Wolfe, Assistant Aviation and Fire Management Officer, Boise National Forest; James R. Moorehead, Branch Chief for Fire Control, Recreation and Land Use, Salmon National Forest, now retired; and James E. Moore, Intermountain Region Fuels Management Officer, now retired.

The knowledge of central Idaho silviculture and forest ecology contributed by Jerry Hamilton, Regional Silviculturist, and Andy Youngblood, Area Ecologist, Intermountain Region, was a great asset to this study.

RESEARCH SUMMARY

This report summarizes available information on fire as an ecological factor for forest habitat types occurring in central Idaho. The forest habitat types described for central Idaho by Steele and others (1981) are grouped into 11 Fire Groups based primarily on fire's role in forest succession.

For each Fire Group, information is presented on (1) the relationship of major tree species to fire, (2) fire effects on undergrowth, (3) fire effects on wildlife, (4) forest fuels, (5) the natural role of fire, (6) fire and forest succession, and (7) fire management considerations.

The Fire Groups are described as follows:

Fire Group Zero—Miscellaneous special habitats.

Fire Group One—Dry limber pine habitat types.

Fire Group Two—Warm, dry habitat types that support open forests of ponderosa pine or Douglas-fir.

Fire Group Three—Warm, moist ponderosa pine habitat types and warm, dry Douglas-fir habitat types usually dominated by ponderosa pine.

Fire Group Four—Cool, dry Douglas-fir habitat types.

Fire Group Five—Moist Douglas-fir habitat types.

Fire Group Six—Grand fir habitat types.

Fire Group Seven—Cool habitat types usually dominated by lodgepole pine.

Fire Group Eight—Dry, lower subalpine habitat types.

Fire Group Nine—Wet or moist, lower subalpine habitat types.

Fire Group Ten—Cold, upper subalpine and timberline habitat types.

Intermountain Research Station
324 25th Street
Ogden, UT 84401

CONTENTS

Page

- Introduction 1
  - Purpose 1
  - Format 1
  - The Fire Groups 2
  - Nomenclature and Terminology 4
- Relationships of Major Tree Species to Fire 4
  - Limber Pine (*Pinus flexilis*) 4
  - Ponderosa Pine (*Pinus ponderosa*) 5
  - Douglas-fir (*Pseudotsuga menziesii*) 6
  - Grand Fir (*Abies grandis*) 6
  - Engelmann Spruce (*Picea engelmannii*) 6
  - Lodgepole Pine (*Pinus contorta*) 7
  - Subalpine Fir (*Abies lasiocarpa*) 7
  - Whitebark Pine (*Pinus albicaulis*) 7
- Undergrowth Response to Fire 8
- Wildlife Response to Fire 13
- Fire Use Considerations 22
  - Heat Effects and Insect Attack 22
  - Frequency of Burning 22
  - Large Woody Debris 22
  - Heat Effects on Soil 22
  - Prescribed Fire Planning 23
- Fire Group Zero: Miscellaneous Special Habitats 23
  - Scree 23
  - Forested Rock 23
  - Wet Meadow 23
  - Mountain Grassland 23
  - Aspen Communities 24
  - Deciduous Riparian Communities 24
  - Fire Management Considerations 24
- Fire Group One: Dry Limber Pine Habitat Types 24
  - Vegetation 24
  - Forest Fuels 24
  - Role of Fire 25
  - Forest Succession 26
  - Fire Management Considerations 27
- Fire Group Two: Warm, Dry Habitat Types that Support Open Forests of Ponderosa Pine or Douglas-fir 27
  - Vegetation 28
  - Forest Fuels 28
  - Role of Fire 28
  - Forest Succession 30
  - Fire Management Considerations 31
- Fire Group Three: Warm, Moist Ponderosa Pine Habitat Types and Warm, Dry Douglas-fir Habitat Types Usually Dominated by Ponderosa Pine 33
  - Vegetation 33
  - Forest Fuels 33
  - Role of Fire 35
  - Forest Succession 36
  - Fire Management Considerations 39
- Fire Group Four: Cool, Dry Douglas-fir Habitat Types 39
  - Vegetation 40
  - Forest Fuels 42
  - Role of Fire 42
  - Forest Succession 42
  - Fire Management Considerations 44
- Fire Group Five: Moist Douglas-fir Habitat Types 45
  - Vegetation 45
  - Forest Fuels 45
  - Role of Fire 45
  - Forest Succession 46
  - Fire Management Considerations 48
- Fire Group Six: Grand Fir Habitat Types 48
  - Vegetation 49
  - Forest Fuels 50
  - Role of Fire 50
  - Forest Succession 50
  - Fire Management Considerations 50
- Fire Group Seven: Cool Habitat Types Usually Dominated by Lodgepole Pine 53
  - Vegetation 54
  - Forest Fuels 55
  - Role of Fire 56
  - Forest Succession 59
  - Fire Management Considerations 60
- Fire Group Eight: Dry, Lower Subalpine Habitat Types 63
  - Vegetation 64
  - Forest Fuels 64
  - Role of Fire 65
  - Forest Succession 65
  - Fire Management Considerations 67
- Fire Group Nine: Wet or Moist, Lower Subalpine Habitat Types 67
  - Vegetation 68
  - Forest Fuels 68
  - Role of Fire 69
  - Forest Succession 69
  - Fire Management Considerations 70
- Fire Group Ten: Cold, Upper Subalpine and Timberline Habitat Types 71
  - Vegetation 71
  - Forest Fuels 71
  - Role of Fire 72
  - Forest Succession 72
  - Fire Management Considerations 73
- References 74
- Appendix A: Habitat Types of Central Idaho 81
- Appendix B: Occurrence and Roles of Tree Species by Habitat Types 84
- Appendix C: Scientific Names of Plants Mentioned in Text 86

Fire Ecology of the Forest Habitat Types of Central Idaho

M. F. Crane
William C. Fischer

INTRODUCTION

Purpose

This report summarizes available fire ecology and management information relating to forest habitat types in central Idaho; specifically, on the Boise, Challis, Payette, and Salmon National Forests; the Fairfield and Ketchum Ranger Districts and Sawtooth National Recreation Area of the Sawtooth National Forest; and the Dubois Ranger District of the Targhee National Forest. The primary purpose of this report is to aid in understanding fire's role in central Idaho forests, especially the role of fire in forest succession.

Habitat types, as defined by Steele and others (1981), are arranged into eleven "Fire Groups" based on the response of the tree species to fire and similar postfire successions. The exception is Fire Group Zero, which is a collection of miscellaneous vegetation types. The actual successional sequence in any given stand depends upon a number of variables, such as preburn vegetation; the size, nature, and severity of the fire; climatic, topographic, and soil factors; and chance. Steele and Geier-Hayes (1982a, 1982b) show an example of the variation possible within a single habitat type. Thus, stands that key to the same habitat type might fall into different Fire Groups.

Habitat types are grouped according to the most probable successional path. A variation frequently encountered in a particular habitat type is mentioned in the text, but infrequent variations may not be noted. A certain reliance is placed on the judgment of the land manager in evaluating the local conditions of any particular site. The groups defined in this report are intended as a general guide, not a definitive treatment.

Format

This report is patterned after **Fire Ecology of Montana Forest Habitat Types East of the Continental Divide** (Fischer and Clayton 1983). The relationships of major tree species to fire, fire effects on wildlife and understory plant species, and fire use considerations relate to the central Idaho region as a whole. Consequently, these sections precede the individual Fire Group discussions of vegetation and soils, forest fuels, fire's natural role, forest succession, and fire management considerations.

Relationship of Major Tree Species to Fire—This section of the report discusses each important tree species in central Idaho with regard to its resistance or susceptibility to fire and its role as a successional component of forest communities. Particular attention is given to fire adaptations such as serotinous cones, corky bark, or seeds that require mineral soil for germination.

Undergrowth Response to Fire—This section summarizes the effect of fire on the response of important understory grass, forb, and shrub species. Fire-adaptive traits or survival strategies are highlighted, and the species' tendency to increase or decrease following fire is noted.

Wildlife Response to Fire—This section contains summaries of the general effects of fire on common central Idaho mammals, reptiles, amphibians, and birds. Fire response of wildlife is largely inferred from expected changes in habitat as a result of fire.

Fire Use Considerations—This brief section summarizes precautions that apply to the use of fire as a management tool. Emphasis is on effective fire use, site protection, minimizing damage to residual stand, and wildlife habitat protection.

Habitat Types and Phases, ADP Codes, and Physiographic Sections—The fire groups are defined with reference to "Forest Habitat Types of Central Idaho" (Steele and others 1981). A complete list of central Idaho forest habitat types is included as appendix A. Habitat types are designated in the standard format of "Series/type, phase," in which "series" refers to the dominant tree in potential climax; "type" denotes a characteristic or indicator understory species; and "phase" provides a further subdivision where needed. The "ADP codes" are automatic data processing codes for National Forest System use. Physiographic sections are as described by Steele and others (1981) and are illustrated in figure 1.

Vegetation—Following the list of habitat types that comprise each group, we describe the characteristic overstory and understory vegetation for that group. Climax and seral species are identified. A complete distribution of tree species showing their successional status is included as appendix B.

Forest Fuels—In this section we characterize the fuels likely to occur on forest sites in the fire group. Emphasis is on the kind and amount of dead, woody material on the forest floor. Where they contribute significantly to fire hazard, live fuels and standing dead fuels are also discussed. Discussions of forest fuels are based on field observations in central Idaho and on inventory data collected on similar habitat types in Montana and northern Idaho.

Role of Fire—This section describes fire and its historic role in shaping the vegetational composition of habitat types in the various fire groups. This section synthesizes

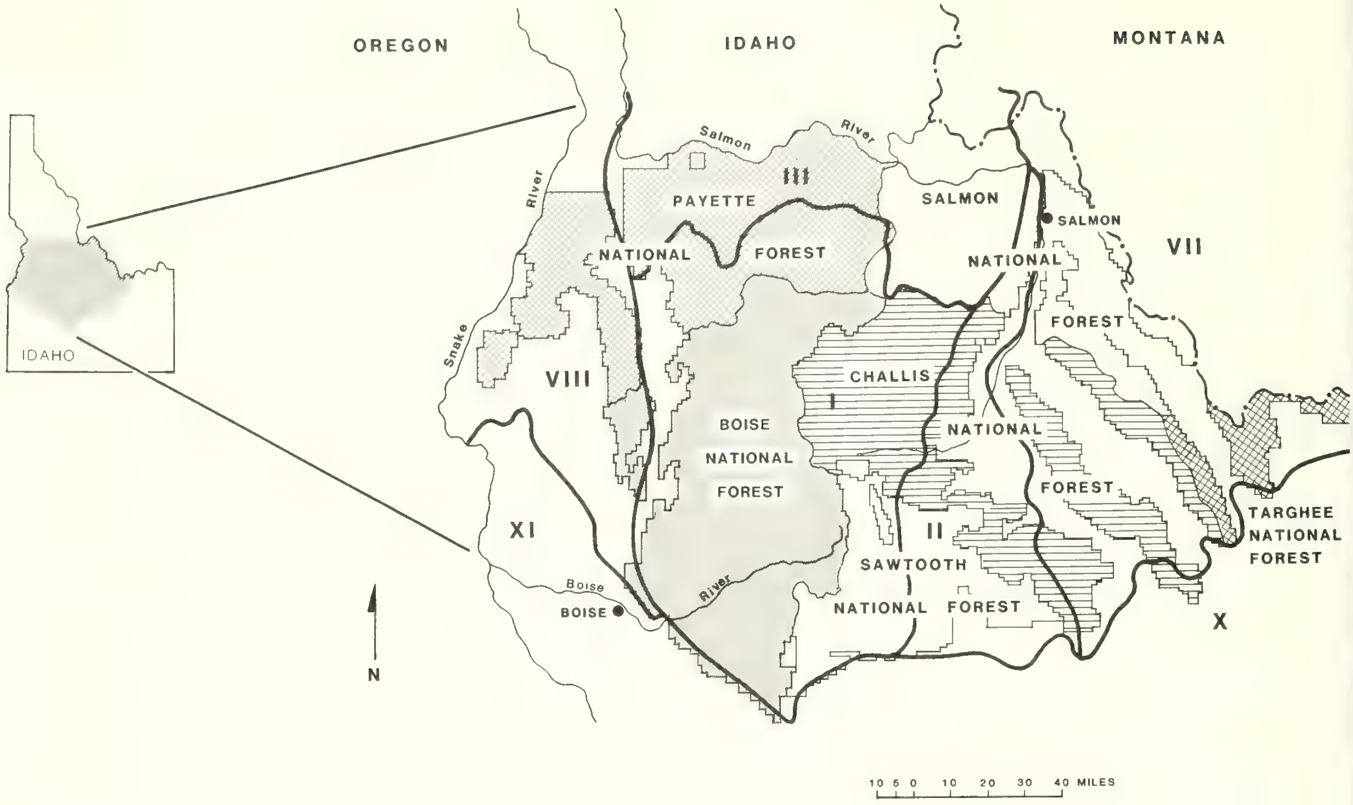


Figure 1—Physiographic sections of central Idaho (I—Southern Batholith, II—Challis, III—Salmon Uplands, VII—Open Northern Rockies, VIII—Wallowa-Seven Devils).

information on susceptibility to fire, fuel conditions, and fire history, gleaned from an extensive search of the literature.

Fire severity is an important factor in shaping the vegetation in a forest stand. For the purpose of this report, three levels of fire severity are recognized: low (light), moderate, and severe (high). A low-severity or cool fire has minimal impact on the site. It burns in surface fuels consuming only the litter, herbaceous fuels, and foliage and small twigs on woody undergrowth. Moderate fires consume litter, upper duff, understory plants, and foliage on understory trees. If fuel ladders exist, individual trees or groups of overstory trees may torch out. A severe fire is one that burns through the overstory, consumes large woody surface fuels, and may remove the entire duff layer over much of the area. Heat from the fire impacts the upper soil layer and may consume the incorporated soil organic matter.

Forest Succession—The generalized succession diagram and accompanying text represent a simplified overview of fire's role in succession for the fire group. The diagram can be used from any stage of stand development, although generally the beginning of secondary succession following a stand-destroying fire is used as the starting point. In order to emphasize the role of fire in each group and keep the diagram simple, other factors that influence vegetational patterns are omitted.

Successional pathway flow charts represent a synthesis of confirmed knowledge and surmised possibilities that form a hypothesis concerning the many influences fire may have on the vegetation of a fire group. The flow charts are similar to those suggested by Kessell and Fischer (1981). Symbols are used for the tree species on this diagram and the flow charts in the following section. The symbols are defined as follows:

Abies grandis, grand fir (ABGR)
Abies lasiocarpa, subalpine fir (ABLA)
Picea engelmannii, Engelmann spruce (PIEN)
Pinus albicaulis, whitebark pine (PIAL)
Pinus contorta, lodgepole pine (PICO)
Pinus flexilis, limber pine (PIFL)
Pinus ponderosa, ponderosa pine (PIPO)
Pseudotsuga menziesii, Douglas-fir (PSME)
Larix occidentalis, western larch (LAOC)

Fire Management Considerations—This section suggests how the preceding information can be used to develop fire management plans that support resource management objectives. The discussion is intended to be suggestive, not dogmatic. Each individual manager is in a much better position than are the authors to relate the information presented in this report to a particular management situation.

The Fire Groups

The forest habitat types of central Idaho have been assembled into 11 fire groups (table 1), which are defined as follows:

Fire Group Zero: Miscellaneous special habitats. This group of special habitats includes scree, forested rock, wet meadows, mountain grasslands, aspen community groves, and deciduous riparian communities.

able 1—Summary of central Idaho habitat type Fire Groups (see appendix A for formal listing of habitat types)

Habitat type	Physiographic section[1]
FIRE GROUP ZERO	
orested rock	
eadow	
rassy bald	
spen	
eciduous riparian, flood plain, nd ravine	
FIRE GROUP ONE	
FL/HEKI	VII
FL/FEID	VII
FL/CELE	VII
FL/JUCO	VII
FIRE GROUP TWO	
PO/STOC	I
PO/AGSP	I, III, VIII
PO/FEID	III, I, VIII
PO/PUTR-AGSP	I, III, VIII
PO/PUTR-FEID	I, III, VIII
PO/SYOR	I, VIII
SME/AGSP	All
SME/FEID-FEID	II, VII
SME/FEID-PIPO	III, I
SME/SYOR	VII, II, I
SME/CELE	II, VII
FIRE GROUP THREE	
PO/SYAL	VIII, III, I
PO/PHMA	I, III
SME/CARU-PIPO	I, VIII, III
SME/CAGE-PIPO	I, VIII, III
SME/BERE-SYOR	I, II, VII
SME/BERE-CAGE	I
SME/SPBE-PIPO	VIII, I
SME/SYAL-PIPO	VIII, III, I
SME/PHMA-CARU	III, I
SME/PHMA-PIPO	I, III, VIII

Habitat type	Physiographic section[1]
FIRE GROUP FOUR	
PSME/ARCO-ASMI	II, VII
PSME/ARCO-ARCO	II, VII
PSME/JUCO	II, VII
PSME/CAGE-SYOR	I, III, II, VII
PSME/CAGE-CAGE	II, I, VII
PSME/CELE	I, II, III, VII
PSME/CARU-FEID	I, III, VII
PSME/CARU-CARU	II, VII, I, III
PSME/SPBE-CARU	II, III, I
PSME/SPBE-SPBE	I, II, III, VII
PSME/SYAL-SYAL	VII, III, I
PSME/ACGL-SYOR	II, VII
PIEN/HYRE	VII
FIRE GROUP FIVE	
PSME/BERE-BERE	I
PSME/OSCH	I, VIII
PSME/VAGL	I, III
PSME/ACGL-ACGL	I, II
PSME/PHMA-PSME	II, VII
PSME/LIBO	III, VII
PSME/VACA	I, III
FIRE GROUP SIX	
ABGR/CARU	VIII,I
ABGR/SPBE	VIII,I
ABGR/ACGL-PHMA	VIII, I
ABGR/ACGL-ACGL	VIII, I
ABGR/LIBO-LIBO	VIII, I
ABGR/LIBO-XETE	III
ABGR/VAGL	VIII, I
ABGR/XETE	VIII, I
ABGR/LIBO-VAGL	VIII, I
ABGR/COOC	I
ABGR/CLUN	VIII, I

Habitat type	Physiographic section
FIRE GROUP SEVEN	
ABGR/VACA	I
ABLA/VACA	I, III
ABLA/VASC-VASC	I, II, III, VII
ABLA/CACA-VACA	III, I
ABLA/CACA-CACA	III, I
ABLA/CACA-LEGL	II, I, III
ABLA/XETE-VASC	III
ABLA/XETE-LUHI	III
ABLA/XETE-VAGL	I, III, VII
ABLA/VAGL-VASC	III
ABLA/CAGE-CAGE	I, III, II, VII
ABLA/CARU	I, II, VII
ABLA/ALSI	III
ABLA/LIBO-VASC	I, III, VII
ABLA/LIBO-XETE	III, I, VII
ABLA/VASC-CARU	I, III, VII
PICO/FEID	I, II, III, VII
PICO/VACA	I, III, VII
PICO/CAGE	I
PICO/VASC	III, VII
FIRE GROUP EIGHT	
ABLA/ACGL	I
ABLA/LIBO-LIBO	I, III, VII
ABLA/VAGL-VAGL	I, III
ABLA/SPBE	I, II
ABLA/JUCO	I, VII
ABLA/ARCO	I, II, VII
FIRE GROUP NINE	
PIEN/GATR	VII
PIEN/CADI	II, VII
PIEN/EQAR	II, VII
ABLA/CABI	I
ABLA/CACA-LICA	III, I
ABLA/STAM-LICA	III
ABLA/STAM-STAM	I, II, VII
ABLA/CLUN-MEFE	III, I
ABLA/CLUN-CLUN	III, I
ABLA/COOC	III
ABLA/MEFE-MEFE	III, VIII
ABLA/MEFE-LUHI	III
FIRE GROUP TEN	
ABLA/RIMO	VII, II
ABLA/LUHI-VASC	III, I
ABLA/LUHI-LUHI	III, I
ABLA/VASC-PIAL	I, II
ABLA/CAGE-ARTR	I, III
PIAL/ABLA	III, I, II
PIAL h.t.'s	II, VII

I - Southern Batholith
II - Challis
III - Salmon Uplands
VII - Open Northern Rockies
VIII - Wallowa-Seven Devils

ire Group One: Dry limber pine habitat types. These abitat types are found almost exclusively in the Challis nd Open Northern Rockies physiographic sections of entral Idaho (fig. 1).

ire Group Two: Warm, dry habitat types that support pen forests of ponderosa pine or Douglas-fir. Mature tands in this group are characterized by an open forest-to-savanna appearance, with an undergrowth of dry-site grasses and forbs.

Fire Group Three: Warm, moist ponderosa pine habitat types and warm, dry Douglas-fir habitat types usually dominated by ponderosa pine. In the absence of fire, Douglas-fir regeneration beneath the ponderosa pine is capable of taking over the site on the Douglas-fir habitat types.

Fire Group Four: Cool, dry Douglas-fir habitat types. These stands are generally found in the continental climate of the Challis and Open Northern Rockies physiographic sections and elsewhere above the cold limits of ponderosa pine. Douglas-fir is often the only conifer on the site.

Fire Group Five: Moist Douglas-fir habitat types. Douglas-fir generally grows well on these sites and dominates the mature stand.

Fire Group Six: Grand fir habitat types. These generally moist and productive sites often support diverse stands of seral tree species. Fire has played an important role in promoting these stands of "mixed forest."

Fire Group Seven: Cool habitat types usually dominated by lodgepole pine. This group includes stands in which fire-maintained lodgepole pine is a dominant seral species as well as stands in which it is a persistent dominant species.

Fire Group Eight: Dry, lower subalpine habitat types. This is a heterogeneous grouping of subalpine habitat types that range from moist to dry. Douglas-fir or a mixture of Douglas-fir and lodgepole pine, sometimes followed by spruce, are the major trees in a successional sequence leading toward a subalpine fir climax forest.

Fire Group Nine: Moist, lower subalpine habitat types. These sites are often dominated by Engelmann spruce. Fires are infrequent but often severe, with long-lasting effects. In some stands, spruce is climax and in the subalpine fir habitat types is a persistent seral species.

Fire Group Ten: Cold, upper subalpine and timberline habitat types. Fires are generally infrequent; the fires that do occur are often limited in extent by discontinuous fuels. Postfire succession is slow, owing to the harshness of the environment.

Nomenclature and Terminology

Trees and undergrowth plants are identified by their common names throughout the text of this report. The list of habitat types at the beginning of each Fire Group discussion reflects the common practice of noting scientific names, abbreviations, and common names. Habitat types are most often identified by abbreviation in the text. Appendix C lists scientific names and common names of plants used in the text.

In this report we use common silvicultural terms to describe general stand conditions such as age, density (stocking), and species composition. Definitions of terms such as even-aged, uneven-aged, overstocked, fully stocked, pure stand, mixed stand, and others have evolved from rather arbitrary and subjective definitions to very precise and quantitative definitions necessary for modern silviculture. Our usage of silvicultural terms conforms to the definitions of the Society of American Foresters (1971, 1958). These definitions tend toward the subjective rather than the quantitative, which is appropriate for the general nature of our discussions. Silviculturists should be aware of this usage so as not to misinterpret the intended level of precision.

RELATIONSHIP OF MAJOR TREE SPECIES TO FIRE

Wildfire, along with climate and topography, has been important in shaping forest ecosystems in the Western United States. It often creates a mosaic of seral vegetational types and age classes within a type. The frequency and severity of fire in an area may be particularly important in determining the species composition on a site (Cattelino and others 1979). The abundance of lodgepole pine, snowbrush ceanothus, and ponderosa pine, for example, is strongly related to fire history in central Idaho (Steele and others 1981).

Physical characteristics determine in large part a species' susceptibility or resistance to fire damage, and this in combination with regeneration strategy determines whether a species will increase or decrease on a site in the aftermath of fire. The fuel situation in close proximity to any individual or group of individuals is, of course, an important factor governing fire damage.

Table 2 summarizes the relative fire resistance of the principal conifers in central Idaho forests. An extensive review and summary of comparative autecological characteristics of northwestern tree species is provided by Minore (1979).

Limber Pine (*Pinus flexilis*)

The degree of cambium heating usually determines the extent of fire injury to limber pines. Young trees are usually killed by any fire that scorches their stems. The bark of young limber pine is too thin to prevent cambium injury, even from a low-intensity fire (Steele in press). Older trees are better able to withstand stem scorch from low-severity fires because the bark around the base of mature trees is often 2 inches (5 cm) thick. The needles of limber pine form into tight clusters around the terminal buds. This shields the buds from heat associated with crown scorch.

Keown (1977) conducted prescribed fire studies on limber pine woodlands at the western edge of the Great Plains in central Montana. His results apply to spring fires when temperatures, relative humidities, and winds were moderate, fuel moistures low, and soil moistures high. Results indicated a strong relationship between fuel type, fire severity, and fire injury to limber pine. On sites where grass was the primary fuel and where trees were present as either scattered individuals or in open stands, fire severity was low and limber pine mortality was light (about 20 percent) even though basal limbs commonly extended to the ground. In similar situations but with a dense undergrowth of shrubs (primarily shrubby cinquefoil), rather than a grass undergrowth, fire severity was high and limber pine mortality often reached 80 percent. The final situation reported by Keown (1977) was where a closed canopy forest bordered shrubland or grassland. Trees in these transition zones were less than 10 ft (3 m) tall, the lower branches often intermingled with ground fuels. The most severe fires occurred on these sites.

Table 2—Relative fire resistance of the more commercially important conifers occurring in central Idaho (source: Flint 1925)

Species	Thickness of bark of old trees	Root habit	Resin in old bark	Tolerance: Branch habit	Tolerance: Stand habit	Relative inflammability of foliage	Lichen growth	Degree of fire resistance
Ponderosa pine	Very thick	Deep	Abundant	Moderately high & open	Open	Medium	Medium to light	Very resistant
Douglas-fir	Very thick	Deep	Moderate	Moderately low & dense	Moderate to dense	High	Heavy to medium	Very resistant
Grand fir	Thick	Shallow[1]	Very little	Low & dense	Dense	High	Heavy	Medium
Lodgepole pine	Very thin	Deep[2]	Abundant	Moderately high & open	Open	Medium	Light	Medium
Engelmann spruce	Thin	Shallow	Moderate	Low & dense	Dense	Medium	Heavy	Low
Subalpine fir	Very thin	Shallow	Moderate	Very low & dense	Moderate to dense	High	Medium to heavy	Very low

[1] The shallow root habit characteristic of grand fir in moist, stream bottom habitats. Trees growing on well-drained, dry mountain slopes develop much deeper root systems (Flint 1925).

[2] Lodgepole pine is generally deep-rooted in well-drained, medium-textured soils. Root development is restricted by layers of coarse soils, impermeable layers, high water tables, or dense stand conditions (Pfister and Daubenmire 1975).

Many limber pine sites in central Idaho are exposed and ocky (Steele and others 1981). Limber pines on these ites are often characterized by profuse branching and a multiple-stemmed appearance. Closer examination of mature, apparently multiple-stemmed trees reveals that many are actually adjoining individuals established in close proximity (Woodmansee 1977). Limber pine has large, wingless seeds incapable of dispersal by winds. Clark's utcracker (*Nucifraga columbiana*) has been identified as he primary, if not the only, reliable limber pine seed ispersal agent responsible for reestablishing limber pine n high-elevation, rocky, windswept sites following stand estruction (Lanner and Vander Wall 1980). Nutcrackers transport seeds as far as 14 miles (22 km) from a seed source to a favored cache site—usually high ridges or ther exposed sites where lack of snow accumulation llows seed retrieval when food is needed (Vander Wall nd Balda 1977; Tomback 1977; Tomback and Kramer 980). Limber pine seed dispersal by ground squirrels was oted by Eggler (1941) in southern Idaho.

Ponderosa Pine (*Pinus ponderosa*)

Ponderosa pine has many fire-resistant characteristics. eedlings and saplings are often able to withstand fire. Development of insulative bark and the tendency for meristems to be shielded by enclosing needles and thick ud scales contribute to the temperature resistance of pole-sized and larger trees.

Propagation of fire into the crown of pole-sized and rger trees growing in relatively open stands on dry sites unusual because of three factors. First, the tendency of ponderosa pine to self-prune lower branches keeps the liage separated from burning surface fuels. Second, the pen, loosely arranged foliage does not lend itself to comustion or the propagation of flames. Third, the thick bark relatively unburnable and does not easily carry fire up he bole or support residual burning. Resin accumulations, owever, make the bark more flammable. Fire resistance open stands is increased further by light fuel loads. When ponderosa pine occurs in open parklike stands, self-pruning is not effective, and such "wolf trees" are susceptible to "torching-out" during moderate to severe surface fires.

Ponderosa pine trees that are heavily infected by the dwarf mistletoe (*Arceuthobium campylopodum*) are more susceptible to fire-related mortality and crown scorch than uninfected or moderately infected trees. Severely infested stands contain increased amounts of both dead surface fuels and live aerial fuels. Also, infected branches, which are often twice normal diameter, resist natural pruning (Koonce 1981).

On moist sites, ponderosa pine often forms two-storied stands that may be quite susceptible to crown fire. The tendency for regeneration to form dense understories, or "dog hair" thickets, on such sites creates fuel ladders that can carry surface fires to the crowns of overstory trees. The fuel ladder effect is often enhanced on moist sites because of the greater level of stocking and the often increased occurrence of lichen and moss in the tree crowns. Crown fires are, consequently, more frequent on moist sites than they are on dry sites. Understory ponderosa pine may also be more susceptible to fire damage because crowded conditions can result in slower diameter growth and heavier loadings of dead fuels. Such trees do not develop their protective layer of insulative bark as early as would otherwise be expected. They remain vulnerable to cambium damage from ground fires longer than their counterparts in open stands. The thick, dense foliage of young stands or thickets also negates the fire-resisting characteristic of open, discontinuous crown foliage normally found in this species. Even if such stands or thickets do not "crown-out," crown scorching is much more likely than in more open situations. The thinning effect of fire is therefore much more pronounced in dense stands than it is in open stands.

Ponderosa pine seedling establishment is favored when fire removes the forest floor litter and grass, exposing mineral soil. Mineral soil exposure and canopy openings caused by fire allow ponderosa pine establishment.

CLEMSON UNIVERSITY LIBRARY
DOCUMENTS DEPT.

Heavy accumulations of litter at the base of pole- and sawtimber-sized tree trunks increase the severity and duration of fire, often resulting in a fire scar or "cat face." Flammable resin deposits around wounds can make the tree susceptible to fire damage and usually cause enlargement of the scars.

Douglas-fir (*Pseudotsuga menziesii*)

Mature Douglas-fir has relatively high resistance to fire damage. Saplings and small poles, however, are vulnerable to surface fires because of their thin, photosynthetically active bark, resin blisters, closely spaced flammable needles, and thin twigs and bud scales. The moderately low and dense branching habit of saplings and poles enables surface fires to be carried into the crown. Even when fire fails to enter the crowns, many saplings and poles are seriously damaged by crown heating or scorching. Older trees develop a relatively unburnable, thick layer of insulative corky bark that provides protection against cool to moderately severe fires, but this protection is often offset by a tendency to have branches the length of the bole. The development of "gum cracks" in the lower trunk, which streak the bark with resin, can provide a mechanism for serious fire injury.

Douglas-fir occurs in open stands, but it also grows in dense stands with continuous understory fuels. Dense sapling and pole thickets can form an almost continuous layer of flammable foliage about 10 to 26 ft (3 to 8 m) above the ground that will support wind-driven crown fires. Even small thickets provide a route by which surface fires can reach the crowns of mature trees. Crowning is often aided by the presence of lichens. Crowning and "torch out" of individual Douglas-fir is also aided by the presence of large, dense witches'-brooms caused by the dwarf mistletoe (*Arceuthobium douglasii*) (Weir 1916; Alexander and Hawksworth 1975).

As with ponderosa pine, heavy fuel accumulations at the base of the tree increase the probability of fire injury. Petersen (1984) determined that bark-char (an indicator of cambium heating) had a strong influence on fire-related tree mortality when 50 percent or more of a Douglas-fir crown was scorched. Heavy litter accumulations may allow injury to the tree roots, causing delayed mortality (Connaughton 1936). Also, resin deposits usually enlarge old scars. Douglas-fir is more susceptible to rot when injured by fire than is ponderosa pine.

Douglas-fir regeneration is generally favored by fire, which reduces vegetational cover and exposes mineral soil so shallow taproots of seedlings can take hold. Ryker (1975) found good establishment of Douglas-fir on litter, indicating that a mineral soil seedbed may not be as critical for establishment of Douglas-fir regeneration on sites as it is for competing species. Severe fire-created microsites may be unfavorable for Douglas-fir regeneration—for example, south-facing burns and clearcuts. Ponderosa pine is often able to regenerate on such hotter, drier microsites.

In central Idaho Douglas-fir occupies the broadest range of environmental conditions of any conifer. This indicates considerable genetic diversity (Rehfeldt 1974).

Grand Fir (*Abies grandis*)

Grand fir (including grand fir and white fir hybrids) is moderately resistant to fire. It is more susceptible to fire damage than ponderosa pine and Douglas-fir, but more resistant than spruce, subalpine fir, and lodgepole pine (USDA-FS 1965). The thick bark contributes to grand fir' fire resistance; however, its relatively dense and low branches, flammable foliage, dense stand habit, and heavy lichen growth all increase its susceptibility to fire damage, Grand fir is very susceptible to bole rot caused by Indian paint fungus (*Echinodontium tinctorium*) when injured by fire (Aho 1977).

Grand fir in central Idaho and northeastern Oregon are the result of introgressive hybridization between two species: *Abies grandis* and *Abies concolor* (Daniels 1969). Inner bark color in these trees may be reddish purple as i is in *Abies grandis* or yellow as it is in *Abies concolor*, which also has thicker (4- to 6-inch or 10- to 15-cm) bark than *Abies grandis* (2-inch or 5-cm). Frederick (1972) found that trees with yellow interior bark had less incidence of decay (primarily caused by the Indian paint fungus) than trees with red inner bark. He also found tha trees on drier sites had less decay than trees on wetter sites.

Steele and others (1981) suggest that hybridization and increased genetic diversity may have allowed grand fir to establish on sites drier than normal for the species in general.

Grand fir's fire resistance is strongly influenced by site. On relatively dry slopes its roots are deep, stands are relatively open, and the bark is thick so that it can withstand cool surface fires. On dry sites, however, grand fir may have relatively poor vigor. On moist sites the trees develop shallow lateral roots rather than a deep taproot, and these are easily killed by fire burning in the thicker duff (USDA-FS 1965). Decay fungi often enter trees through fire scars (Aho 1977). All factors considered, grand fir is not benefited by fire in central Idaho nearly a much as its competitors.

Fisher (1935) compared germination on several differen seedbeds and found grand fir germinated best on ash. Seedlings will establish and grow in full sunlight, but earl growth of grand fir is favored by partial shade (USDA-F 1965).

Engelmann Spruce (*Picea engelmannii*)

Engelmann spruce is easily killed by fire. The dead, dr flammable lower limbs, low-growing canopy, thin bark, and lichen growth in the branches contribute to the species' vulnerability. The shallow root system is readily subject to injury from fire burning through the duff. Large, old spruce may occasionally survive one or more light fires (Arno 1980), but deep accumulations of resinou needle litter around their bases generally make them particularly susceptible to fire damage. Survivors are often subjected to successful attack by wood-destroying fungi that easily enter through fire scars. The high susceptibili of spruce to fire damage is mitigated in part by the generally cool and moist sites where it grows. Despite its susceptibility to fire, spruce will usually be favored at th expense of subalpine fir where the two grow together (Wellner 1970).

Spruce is not an aggressive pioneer. It is a moderate seed producer, but viability is rated good and the vitality persistent (Alexander and Sheppard 1984). Initial establishment and early growth of seedlings is usually slow. Germination is often good on mineral soil and burned seedbeds where a constant supply of moisture is available and some large debris is left scattered about the site (Roe and others 1970). A survey of spruce regeneration in the Intermountain Region showed that mechanically exposed mineral soil was superior to all other types of seedbeds for seedling establishment and early survival (Roe and Schmidt 1964). Spruce seedlings will occur as members of a fire-initiated stand with other seral species. Spruce's shade tolerance allows it to establish and grow beneath a canopy of lodgepole pine or other seral species.

Restocking after fire will occur more quickly if some spruce seed trees survive within the burn than if regeneration is dependent on seed from trees at the fire edge. Pockets of spruce regeneration often become established around such surviving seed trees up to a distance of 300 feet (90 m), the effective seeding distance for spruce.

Lodgepole Pine (*Pinus contorta*)

Lodgepole pine is ranked as being moderately resistant to fire (Brown and Davis 1973; Tackle 1961; Starker 1934). It has thin (<0.4 inch or 1 cm thick) bark and a moderately high and open crown. The lower branches of this shade-intolerant tree self-prune in dense stands.

Lodgepole pines' most noteworthy adaptation to fire is its serotinous cones. Temperatures of 113 °F (45 °C) may be required to melt the resin binding the scales and release the small, winged seeds. Steele and others (1981) state that in central Idaho most lodgepole pine cones are nonserotinous. On the Boise and Payette National Forests the percentage of serotinous-cone-bearing trees was found to vary from 0 to 12 percent (Lotan 1975). A more complex situation than open vs closed cones may exist, however, according to Perry and Lotan (1977). Cones may have a wide variety of opening temperature requirements, hence old and new cones on the same tree may open at different temperatures. Cone habit in a given locality cannot be assumed. It must be determined by stand examination.

Aside from serotinous cones, other silvical characteristics (USDA-FS 1965; Tackle 1961) that contribute to lodgepole pine's success in dominating a site following fire are:

1. Early seed production. Cones bearing viable seed are produced by trees as young as 5 years in open stands and by trees 15 to 20 years old in more heavily stocked stands. This feature not only allows relatively young stands to regenerate a site following fire, but the seed from open cones can fill in voids left by the original postfire seeding from serotinous cones.
2. Prolific seed production. Good cone crops occur at 1- to 3-year intervals, with light crops intervening.
3. High seed viability. Seeds in 80-year-old serotinous cones, for example, have been found to be viable.
4. High seedling survival and rapid early growth, especially on mineral soil seedbeds exposed to full sunlight.

Lodgepole pine's success in revegetating a site following fire may result in dense, overstocked stands. Such stands are likely to stagnate and subsequently succumb to one or more destructive agents over their lifespan, for example, natural thinning, snow breakage, windthrow, dwarf mistletoe (*Arceuthobium americanum*) infestation, and mountain pine beetle (*Dendroctonus ponderosae*) attack. The individual or combined effect of these agents is often a significant buildup of dead, woody fuel on the forest floor. Thus, the stage is set for another stand-destroying wildfire.

Subalpine Fir (*Abies lasiocarpa*)

Subalpine fir is rated as the least fire-resistant Northern Rocky Mountain conifer because of its thin bark, resin blisters, low and dense branching habit, and moderate-to-high stand density in mature forests. As a result, fire most often acts as a stand-replacement agent when it burns through a subalpine fir forest. Even light ground fires can kill the cambium or spread into the ground-hugging branches and from there up into the crown. Subalpine fir is very susceptible to decay following injury.

Subalpine fir may begin producing cones when only 20 years old, but maximum seed production is by dominant trees 150 to 200 years old. Subalpine fir has the ability to germinate and survive on a fairly wide range of seedbeds.

Subalpine fir can occur in a fire-initiated stand with Douglas-fir, lodgepole pine, and other seral species because it germinates successfully on a fire-prepared seedbed. Subalpine fir is usually, however, a slow-growing minor component, and is usually not as conspicuous as less tolerant species.

In a closed canopy situation, establishment and early survival of subalpine fir are not hampered by deep shade. Subalpine fir can tolerate low light conditions better than most associated species. Engelmann spruce will, however, often grow faster than subalpine fir where light intensity exceeds more than 50 percent of full sunlight. Subalpine fir is shade-tolerant and is the indicated climax species on many sites containing lodgepole pine. Where a seed source exists, the fir will, consequently, invade and grow in the understory of most lodgepole stands. Given a long enough fire-free period, subalpine fir will replace lodgepole pine on sites where it is the indicated climax.

Whitebark Pine (*Pinus albicaulis*)

Whitebark pine is a semitolerant or midtolerant species (Arno and Hoff, in press) that has been known to invade burned sites. It occurs as the potential climax species on alpine timberline and exceptionally dry sites, but is a seral species in upper subalpine forests (Arno in press). Whitebark pine is moderately fire resistant. It has a relatively thin bark and is susceptible to fire injury from surface fires that kill the cambium. Whitebark pine's dry, exposed habitat and open structure tend to reduce its vulnerability. The fact that whitebark pine often reaches ages of 500 years or more reflects the reduced fire threat.

Whitebark pine may occur as small groups of trees, especially near its lower elevational limit where it appears with lodgepole pine, subalpine fir, and Engelmann spruce. The general impression of whitebark pine communities, however, is that of open stands where the undergrowth is continuous low shrubs, forbs, and grasses. Occasionally larger shrubs and stunted trees occur.

Fires that burn in the undergrowth are usually of low-to-moderate severity. The low, ground-hugging crowns of associated conifers can provide a fuel ladder, and downfall in the vicinity of mature trees locally increases crown fire potential; hence, severe fires are possible.

Severe wildfires starting in lower elevations can spread throughout the upper elevation forests to timberline. Although the open nature of a whitebark pine forest acts as a firebreak, many trees can be killed under these conditions. The most common fires are lightning fires that do not spread far. During extended periods of high fire danger, however, these usually benign fires may spread downhill into dense lower elevation forests.

Clark's nutcracker disperses whitebark pine seed as it does limber pine seed. The nutcracker caches the large, wingless seeds in the soil. Unretrieved seed, which are stored at an average soil depth of about 0.8 inch (2 cm), germinate and establish new pines (Hutchins and Lanner 1982; Tomback 1982; Lanner 1982). Experimental results indicate a 56 percent seedling survival rate over the first year; 25 percent by the fourth year (Tomback 1982). No other reliable seed dispersal agent for whitebark pine has been documented in the literature, although dispersal by ground squirrels was observed during cone collecting efforts on Teton Pass in the fall of 1984 (J. Hamilton 1985). According to Tomback (1982), Clark's nutcracker is in large part responsible for the "pioneering" status of whitebark pine in subalpine habitats.

UNDERGROWTH RESPONSE TO FIRE

Many of the common shrubs and herbaceous plants of central Idaho forests can renew themselves from plant parts that survive fire. Other plants are quite susceptible to fire kill and must reestablish from off-site seed, buried seed, or invasion from unburned patches within or immediately adjacent to the burned area.

Current understanding of the process of plant succession following fire in Inland Northwest forests and its management implications are summarized by Stickney (1982):

> . . . the severity of the disturbance treatment directly affects the representation of the survivor component in the postfire vegetation. Since survivors derive from plants already established at the time of disturbance, it is possible, by pretreatment inventory, to determine the potential composition for the survivor component. For this reason it also follows that forest stands with little undergrowth vegetation could be expected to have a sparse or limited survivor component following disturbance. In addition, if the colonizer component is composed mostly of shade-tolerant climax-like species the rate of survivor recovery can be expected to be slow. Nearly all of our native forest shrub species are capable of surviving burning, and they can therefore be expected to function as survivors. A majority of the predisturbance forest herb species also demonstrated the ability to survive fire, particularly those species with underground stems (rhizome) or rootcrowns (caudex). As a generalization, the more severe the fire treatment to vegetation, the less the survivor component. In the drier, more open forest types this usually results in a reduction of amount, but not major changes in composition. However, in the moister forest types, where the undergrowth is made up of more mesic shade-tolerant species, marked changes in postfire composition can occur as increasing severity reduces survivor representation.
>
> The severity of disturbance treatment (particularly fire) influences the potential for colonizer presence in two ways: (1) the degree of severity creates the character of the ground surface on which colonizer seedlings germinate, and (2) it activates onsite stored seed. Generalizing, the more severe the disturbance treatment the more favorable the site becomes for colonizers. As the extent of exposed mineral soil increases, the ground surface becomes more favorable as a site for germination and establishment of colonizer plants. Increases in treatment severity also favor germination of ground-stored seeds by increasing their exposure to light or heat.
>
> Predicting the occurrence of colonizers in postdisturbance vegetation is much less certain than predicting for survivors, but knowledge of the previous succession history can provide the potential composition of residual colonizers. Locally this information is often available from an adjacent or nearby clearcut. Least predictable is the offsite colonizer component, for its occurrence is dependent on the timing of the disturbance to the availability and dispersal of offsite airborne seed. Even in this case reference to local clearcuts can provide some idea of the composition for the most common offsite colonizer species likely to occur.

Table 3 summarizes current knowledge of plant responses to fire for some species that occur in central Idaho forests. Actual plant response to fire depends on many factors, including moisture content of the soil and duff, physiological stage of the plant, and the severity of the fire, especially in terms of the amount of heat that travels downward through the duff and upper layer of so

Table 3—Summary of postfire survival strategy and fire response information for some shrubs and herbaceous plants occurring in forests in central Idaho (sources: Armour and others 1984; Bradley 1984; Britton and others 1983; Crane and others 1983; Daubenmire and Daubenmire 1968; Freedman 1983; Hironaka and others 1983; Keown 1978; Klemmedson and Smith 1964; Kramer 1984; Lotan and others 1981; Lyon 1966, 1971; Lyon and Stickney 1976; McLean 1969; Miller 1977; Morgan and Neuenschwander 1984; Mueggler 1965; Noste 1985; Rowe 1983; Stickney 1981; Viereck and Dyrness 1979; Viereck and Schandelmeier 1980; Volland and Dell 1981; Woodard 1977; Wright 1980, 1978, 1972; Wright and Bailey 1980; Wright and others 1979; Zager 1980; Zimmerman 1979)

Species	Fire Group(s)	Fire survival strategy	Comments on fire response
SHRUBS:			
Acer glabrum Rocky Mountain maple	4,5,6,8	Sprouts from surviving crown.	Usually increases following fire.
Alnus sinuata Sitka alder	7,8,9	Sprouts from surviving root crown.	Usually increases on site following fire. Early seed production (after 5 years) aids in this increase.
Amelanchier alnifolia serviceberry	3,4,5,6	Sprouts from surviving large rhizome.	Pioneer species which usually survives even severe fires especially if soil is moist. Coverage usually increases following fire.
Arctostaphylos uva-ursi kinnikinnick	4,5,6,7,9	Sprouts from surviving root crown located below soil surface. Fibrous roots and stolons (runners) at soil surface.	Susceptible to fire-kill. Will survive some low severity fires when duff is moist and therefore not consumed by fire. May invade burned area from unburned patches.
Artemesia tridentata big sagebrush	2,4,7,10	Wind-dispersed seed; residual seed in soil. Subspecies *vaseyana* stores seed in soil, which germinates when heated by fire.	Very susceptible to fire-kill. Recovery is hastened when a good seed crop exists before burning.
Berberis repens creeping Oregon grape	3,4,5,7,8	Sprouts from surviving rhizomes, which grow 0.5 to 2 inches (1.5 to 5 cm) below soil surface.	Moderately resistant to fire-kill. Will usually survive all but severe fires that remove duff and cause extended heating of upper soil.
Ceanothus velutinus snowbrush ceanothus	4	Soil-stored seed germinates following heat treatment. It can also sprout from root crowns following a cool fire.	Usually increases following fire, often dramatically.
Cercocarpus ledifolius curlleaf mountain-mahogany	1,3,4	Does not sprout or sprouts weakly.	Seriously damaged by severe fires. Seeds need mineral soil to germinate.
Holodiscus discolor oceanspray	6	Sprouts from surviving root crown. It also has soil-stored seed that may require heat treatment.	Moderately resistant to fire-kill. Is often enhanced by fire. Seedlings favored by mineral soil exposure.
Juniperus communis common juniper	1,4,7,8,10	Bird-dispersed seed.	Very susceptible to fire-kill. Seed commonly requires long germination period.
Ledum glandulosum Labrador-tea	7,9,10	Fire avoider, rhizomes. *L. groenlandicum* rhizomes about 15 to 30 cm deep.	Unknown probably poor response. *L. groenlandicum* cover is much reduced by fire.
Linnaea borealis twinflower	5,6,7,8,9	Sprouts from surviving root crown located just below soil surface. Fibrous roots and stolons (runners) at soil surface.	Susceptible to fire-kill. May survive some cool fires where duff is moist and not consumed. Can invade burned area from unburned patches.
Lonicera utahensis Utah honeysuckle	5,8,9	Sprouts from surviving root crown.	Often a reduction in cover and frequency following fire.
Menziesia ferruginea rusty menziesia	9,10	Sprouts from surviving root crown.	Susceptible to fire-kill. Moderate to severe fires reduce survival and slow redevelopment.
Pachistima myrsinites mountain lover	6,7,8	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Usually survives low to moderate severity fires that do not consume the duff and heat soil excessively. Usually increases.
Physocarpus malvaceus shallow ninebark	3,5,6,8	Sprouts from surviving root crown.	Susceptible to fire-kill. Roots may be damaged by moderate to severe fires. Often a slight decrease following fire.

(con.)

Table 3 (Con.)

Species	Fire Group(s)	Fire survival strategy	Comments on fire response
Prunus virginiana chokeberry	3,4	Sprouts from surviving root crown.	Usually increases coverage following fir
Purshia tridentata antelope bitterbrush	2,3,4,7	A weak sprouter. Animal-dispersed seed and seed caches present on area prior to fire.	Very susceptible to fire-kill, especially ir summer and fall. Decumbent growth fo sprouts vigorously, columnar form does not. Spring burns enhance sprouting, fa burns are best for regeneration by seed
Ribes cereum wax currant	2,3,4,5,7,8	A weak sprouter from root crown, soil-stored seed.	Susceptible to fire-kill. Seldom survives severe fire.
Ribes lacustre prickly currant	4,6,9	Sprouts from surviving root crown located beneath soil surface.	Resistant to fire-kill. Usually increase even after a severe fire. Seedlings may establish after low or moderate fires.
Ribes viscosissimum sticky currant	4,5	A weak sprouter, soil-stored seed may require heat treatment.	Susceptible to fire-kill. Relatively shade intolerant. May contribute substantially t postfire revegetation.
Rosa gymnocarpa baldhip rose	3,5,6	Sprouts from surviving root crowns.	
Rosa woodsii Woods rose	4,5,6	Sprouts from surviving root crowns.	Some ecotypes can spread by root sprouting.
Rubus parviflorus thimbleberry	5,6	Sprouts from surviving root rhizomes. It also has soil-stored seed.	May be enhanced by fire, producing multiple sprouts.
Salix scoulerana Scouler willow	3,4,5,6	Sprouts from surviving root crowns. Wind-dispersed seed.	Resprouts vigorously after fire. Height growth may be dramatic.
Shepherdia canadensis russet buffaloberry	4,5,6,7,8	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that do not consume duff or heat sc extensively.
Sorbus scopulina mountain ash	2,3,4,5,6,7, 8,9,10	Sprouts from surviving root crown.	
Spiraea betulifolia white spirea	3,4,5,6,7,8	Sprouts from surviving root crown and from rhizomes which grow 2 to 5 inches (5 to 13 cm) below surface.	Resistant to fire-kill. Will usually survive even a severe fire. Generally increases coverage following fire.
Symphoricarpos albus common snowberry	2,3,4,7,8,10	Weak sprouter from surviving root crown.	Moderately resistant to fire-kill. Usually maintains prefire frequency and coverage
Symphoricarpos albus mountain snowberry	7,8,9,10	Weak sprouter from surviving root crown.	Moderately resistant to fire-kill. Usually maintains prefire frequency and coverage
Vaccinium globulare blue huckleberry	5,6,7,8,9	Sprouts from surviving rhizomes.	Increases after cool fires. May take longe to resprout following severe fires.
Vaccinium scoparium grouse whortleberry	6,7,8,9,10	Sprouts from surviving rhizomes which grow in duff layer or at surface of soil.	Moderately resistant to fire-kill. Will usually survive mild to moderately severe fires that fail to consume the lower layer of duff.
FORBS:			
Achillea millefolium yarrow	1,2,4,5	Sprouts from short shallow rhizome.	Reduced by severe fires.
Adenocaulon bicolor trail-plant	6,9	Short, compact surface rhizomes. Airborne seed.	Decreased by fire or other disturbance. Postfire development slow.
Arnica cordifolia heartleaf arnica	4,5,6,7,8,9	Sprouts from surviving rhizomes which creep laterally from 0.4 to 0.8 inch (1 to 2 cm) below soil surface. Wind dispersed.	Susceptible to fire-kill. Shoots produce small crowns within the duff easily killed by all but mild fires, which occur when duff is moist. May rapidly invade burned area via windborne seed.
Arnica latifolia broadleaf or mountain arnica	7,8,9,10	Sprouts from surviving rhizomes which creep laterally in the soil.	Susceptible to fire-kill. Will usually survive mild to moderately severe fires. May exhibit rapid initial regrowth accompanied by heavy flowering and seedling establishment.

(con.)

Table 3 (Con.)

Species	Fire Group(s)	Fire survival strategy	Comments on fire response
Aster conspicuus showy aster	5,8	Sprouts from surviving rhizomes which mostly grow from 0.5 to 2 inches (1.5 to 5 cm) below soil surface	Moderately resistant to fire-kill. Will usually survive mild to moderately severe fires that do not result in excessive soil heating. May rapidly increase following fire.
Astragalus miser weedy milkvetch	4,5	Sprouts from buds along surviving taproot which may be 2 to 8 inches (5 to 20 cm) below the root crown.	Resistant to fire-kill. Can regenerate from taproot even when entire plant crown is destroyed. Can send up shoots and set seed the first year. May increase dramatically following fire. Note: milkvetch is poisonous to sheep and cattle.
Balsamorhiza sagittata arrowleaf balsamroot	2,3,4,5	Regrowth from surviving thick caudex	Resistant to fire-kill. Will survive even the most severe fire.
Clintonia uniflora queencup beadlily	9	Sprouts from surviving rhizomes.	Usually decreases following fire. Postfire environment evidently not conducive to rapid recovery.
Clematis columbiana Columbia clematis	5,6,7,9	Sprouts from surviving root crowns.	
Coptis occidentalis western goldthread	7,9	Slender rhizomes.	Fire sensitive; generally is reduced following fire.
Disporum trachycarpum wartberry fairybell		Rhizomes.	*D. hookeri* is initially decreased by fire but recovers to preburn levels relatively rapidly.
Epilobium angustifolium reweed	2,3,4,5,6,7, 8,9,10	Wind-blown seed and sprouts from rhizomes.	Needs mineral soil to establish, can persist vegetatively and flower the first summer following a fire. Large increase following fire.
Equisetum arvense ommon horsetail	3,7,8,9	Spreading rhizomes and wind-dispersed propagules.	Frequency unchanged or increased after fire. Especially favored by moist mineral soil exposure.
Fragaria virginiana wild strawberry	5,6,8	Sprouts from surviving stolons (runners) at or just below soil surface.	Susceptible to fire-kill. Will often survive cool fires that do not consume duff because of high duff moisture content.
alium triflorum weetscented bedstraw	8,9	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Usually a sharp decrease following severe fire. Can increase following spring and fall fires.
liamna rivularis	5	Soil-stored seed.	Responds vigorously to severe burning, a pioneer species.
athyrus nevadensis usick's peavine	2,3,6,8,9	Rhizomes. In *L. ochroleucus* these are 0.5 to 2 inches (1.5 to 5 cm) below the mineral soil surface.	*Lathyrus* spp. exhibits intermediate susceptibility. *L. hijugatus* increases somewhat or remains unchanged in frequency after fire.
loldavica parviflora merican dragon head	5	Residual seed in duff.	Dramatic increase following fire. Decreases after second year.
smorhiza chilensis mountain sweet-cicely		Well-developed taproot, sometimes a branched caudex. Seeds transported by animals.	Little change or some increase in cover. Flowering stimulated by opened canopy.
enstemon wilcoxii Wilcox's penstemon	2,3,4,5,6,8	Surficial branched woody caudex. Seeds sprout in first postfire year.	Adult plants susceptible, but often many seedlings postfire.
teridium aquilinum	6,7,8,9	Sprouts from surviving rhizomes.	Spreads vigorously following fire.
yrola secunda debells pyrola	5,6,8,9	Sprouts from surviving rhizomes which grow mostly in the duff or at soil surface.	Susceptible to fire-kill. Coverage frequently reduced following fire. May survive cool fires when duff moisture is high.
enecio streptanthifolius rowleaf groundsel	5	Nonrhizomatous, regenerates from off-site seed.	

(con.)

Table 3 (Con.)

Species	Fire Group(s)	Fire survival strategy	Comments on fire response
Smilacina racemosa feather or false Solomon's seal	5,6,8	Sprouts from surviving stout, creeping rhizomes.	Moderately resistant to fire-kill. May be killed by fires that remove duff and heat soil excessively. Usually maintains prefire frequency.
Smilacina stellata starry Solomon's seal	6,8	Sprouts from surviving creeping rhizomes.	Moderately resistant to fire-kill. May be killed by fires that remove duff and heat upper soil. Frequency often reduced following fire.
Streptopus amplexifolius twisted stalk	6,7,8,9	Extensively rhizomatous.	Decreased by fire.
Thalictrum occidentale western meadowrue	5,6,7,8,9	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Frequency usually reduced following fire. May survive cool fires that do not consume duff.
Trantvetlaria carolinensis false bugbane	7,9	Widely spreading rhizomes.	Slight decrease after fire.
Xerophyllum tenax beargrass	6,7,9,10	Sprouts from a surviving stout surface rhizome.	Sensitive to fire. Will increase after fires that do not consume duff. Sprouts will flower vigorously after a fire until new overstory canopy develops.
GRASSES:			
Agropyron spicatum bluebunch wheatgrass	1,2,4,5	Seed germination and some sprouts from surviving rhizomes.	Usually not seriously damaged by fire. Response depends on severity of fire and physiological state of plant. Damage will be greatest following dry year.
Bromus tectorum cheatgrass	1,2,3	Seed reserves in soil; variable germination seasons; relatively high heat resistance of seed.	Individual plants susceptible to heat-kill. Surviving seed germinate at various times during the year—fall, late winter, spring. Early summer burns before seed matures are more effective for controlling cheatgrass than midsummer and fall burns.
Calmagrostis canadensis bluejoint	2,3,4,5,6,7, 8,9	Invader, wind-disseminated seed; also an enduring sprouter.	Increases on wet to moist postfire sites.
Calamagrostis rubescens pinegrass	3,4,5,6,7,8	Sprouts from surviving rhizomes which grow within the top 2 inches (5 cm) of soil.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that do not completely consume duff. Burned areas are often successfully invaded by pinegrass.
Carex geyeri elk sedge	3,4,5,6,7, 8,10	Sprouts from surviving rhizomes.	Invades burned areas and forms dense stands. Often decreases immediately following fire; then increases.
Carex rossii Ross sedge	6,7,10	Seed stored in duff or soil germinates when heat treated. Sprouts from surviving rhizomes.	Increased coverage usually results following most fires severe enough to heat but not completely consume duff. Often increases.
Festuca idahoensis Idaho fescue	1,2,4,5,7,10	Seed germination and survival of residual plant.	Susceptible to fire-kill. Response will vary with severity of fire and physiological state of plant. Can be seriously harmed by hot summer fires. Only slightly damaged during spring when soil moisture is high or in fall when growing has ceased.
Koeleria cristata junegrass		Seed germination and residual plant survival.	Susceptible to fire-kill. Response will vary according to fire severity and physiological state of plant.
Luzula hitchcockii woodrush	7,10	Sprouts from surviving rhizomes.	Often a slight increase following fire.

WILDLIFE RESPONSE TO FIRE

The effects of fire on wildlife are primarily secondary effects; fire creates, destroys, enhances, or degrades favorable habitat (food supply, cover, shelter, physical environment) thereby causing changes in the subsequent occurrence and abundance of animal species on a burned area (fig. 2). Table 4 lists the probable effects of fire on some mammals, reptiles, and amphibians that occur in central Idaho forests. The indicated fire effects are either inferred from habitat requirements or from studies conducted on specific wildfire or prescribed fire areas. The user is reminded that a major problem in attempting any generalization about the effects of fire on wildlife is the variation in fires: intensity, duration, frequency, location, shape, extent, season, fuels, sites, soils, and prescribed fires as compared to wildfires (Lyon and others 1978).

The response of bird species to fire has been hypothesized by Kramp and others (1983), using a classification suggested by Walter (1977). Four fire-response categories are recognized in this classification: fire-intolerant, fire-impervious, fire-adapted, and fire-dependent.

Fire-intolerant species decrease in abundance after fire and are present only in areas characterized by very low fire frequency and severity. Characteristic central Idaho species include the hermit thrush (*Catharus guttatus*), red-breasted nuthatch (*Sitta canadensis*), and brown creeper (*Certhia familiaris*), which are closely associated with closed canopy forests. These birds prefer a dense nesting and foraging cover but do not use fire-created openings.

Fire-impervious bird species are unaffected by fire; they neither increase nor decrease because of fire. Bird species whose niche incorporates successional and climax community types may be expected to show the highest flexibility in response to fire.

Fire-adapted species are associated with habitat that is characterized by recurring fires of various severity. These species, however, do not depend on fire. Fire-adapted species may also occupy areas with the same frequency-severity ratio as fire intolerant species. Fire-adapted birds include those that use both dense canopy areas and openings; a predator such as the sharp-shinned hawk (*Accipiter striatus*) is an example. Such birds benefit by increased hunting success in recent burns, but generally depend on unburned habitat for nesting sites.

Fire-dependent species are associated with both fire-dependent and fire-adapted plant communities. When fire frequency decreases, these plant communities shift to fire-neutral or fire-intolerant types, and fire-dependent birds are unable to persist. In Central Idaho the blue grouse (*Dendragapus obscurus*) is probably fire-dependent. The bird requires medium to large fire-created forest openings with shrubs-grass-forb vegetation for breeding adjacent to dense foliage conifers for roosting and hooting.

Table 5 presents fire tolerance for some central Idaho bird species.

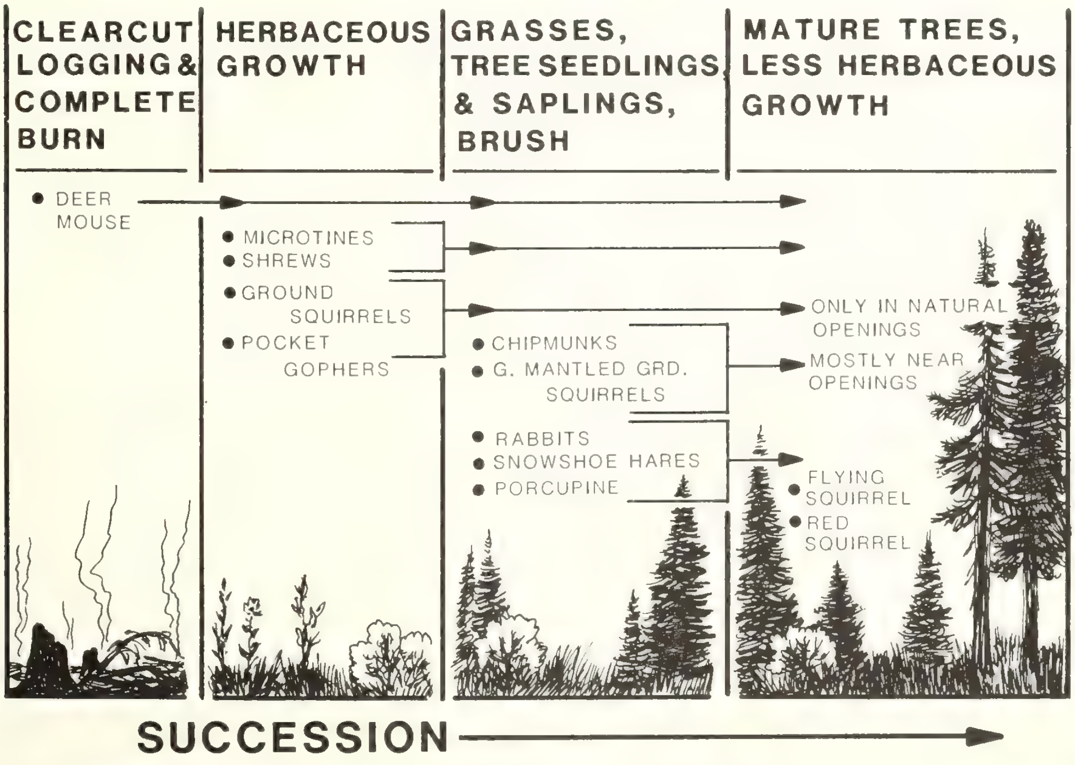

CLEARCUT LOGGING & COMPLETE BURN
HERBACEOUS GROWTH
GRASSES, TREE SEEDLINGS & SAPLINGS, BRUSH
MATURE TREES, LESS HERBACEOUS GROWTH
DEER MOUSE
MICROTINES
SHREWS
GROUND SQUIRRELS
POCKET GOPHERS
ONLY IN NATURAL OPENINGS
CHIPMUNKS
G. MANTLED GRD. SQUIRRELS
MOSTLY NEAR OPENINGS
RABBITS
SNOWSHOE HARES
PORCUPINE
FLYING SQUIRREL
RED SQUIRREL
SUCCESSION

Figure 2—Small mammals found in the successional stages after clearcut logging and burning (Ream and Gruell 1980).

Table 4—Probable effects of fire on some central Idaho mammals, reptiles, and amphibians (major sources: Allen 1983; Beecham and others 1984; Bendell 1974; Bernard and Brown 1977; Black and Tabor 1977; Chandler and others 1983; Halvorson 1981, 1982; Hobbs and Spowart 1984; Kelsall and others 1977; Lyon and others 1978; Maser and others 1981; Melquist and Hornocker 1983; Peek and others 1985; Ream 1981; Thomas 1979; Verner and Bass 1980; Wright and Bailey 1982)

Species	Fire Group(s)	Habitat considerations	Fire effects
MARSUPIALIA (marsupials):			
Oppossum *Didelphis virginiana*	2,3,4,5,6	Prefers riparian zones but highly adaptable. Nests in hollow trees, brush piles.	Severe fires may destroy nest sites. Relatively impervious to cool surface fires.
INSECTIVORA (insect eaters):			
Masked shrew *Sorex cinereus*	2,3,4,5,6,7,8,9,10	Prefers moist situations in forest or open. Requires a mat of ground vegetation for cover; stumps, logs, and slash piles for nest sites.	May be temporarily eliminated from severe burns where duff and ground cover are absent. Some direct mortality of nestlings possible.
Vagrant shrew *S. vagrans*	2,3	Prefers streamsides, marshes, and bogs, but also occurs in moist soil; mat of ground vegetation or debris for cover. Stumps, rotten logs for feeding and nesting.	May be temporarily eliminated from severe burns where duff, ground cover and debris are absent. Some direct mortality of nestlings possible.
Water shrew *S. palustris*	All	Prefers riparian areas at middle and high elevations. Requires small, cold streams and wet areas with protected banks and ground cover.	May be eliminated from severely burned areas where duff and streamside cover have been removed.
Pacific mole *Scapanus orarius*	2,3,4,5,6,7,8,9,10	Rarely appear above surface. Prefer well-drained soils.	Relatively impervious to fires of average severity.
CHIROPTERA (bats):			
Little brown myotis *Myotis lucifugus*	2,3,7,8,9,10	Common in forest and at the forest edge. Requires snags and tree holes for roosting and for maternity colony sites.	Severe fire may destroy roosting and breeding sites. Relatively impervious to cool and moderate fires.
Small-footed myotis *M. subulalus*	2,3,7,8,9,10	Most common in ponderosa pine zone. May use hollow trees and snags for roosting and breeding.	Severe fires may destroy roosting and breeding sites but with little impact on populations.
Silver-haired bat *Lasionycteris noctivagrans*	2,3	Feeds in openings and adjacent to mature forest. Roosts in tree foliage; uses hollow trees and snags for breeding.	Severe fires may destroy some roosting and breeding sites. Relatively impervious to fire.
Big brown bat *Eptesicus fuscus*	1,2,3	Common over grassy meadows surrounded by ponderosa pine. Roosts and breeds in hollow trees and snags.	Severe fires may reduce breeding and roosting sites. Relatively impervious to fire.
Townsend's big-eared bat *Plecotus townsendi*	7,8,9,10	May be found in forests up through spruce-fir zone. Not a tree user.	Relatively impervious to fire.
LAGOMORPHA (pikas, hares, and rabbits):			
Pika *Ochotona princeps*	All	Prefers high-altitude talus slopes adjacent to forest openings containing grasses and forbs.	Relatively impervious to fire. Severe fires may create favorable forest openings with abundant grass-forb food supply.
Mountain cottontail *Sylvilagus nuttalli*	1,2,3	Prefers dense, shrubby undergrowth and pole-sized trees for cover. Uses downed logs for cover and nest sites.	Temporarily eliminated from severe burns but reoccupies as shrub cover increases. Will continue to use less than severe burns.
Snowshoe hare *Lepus americanus*	7,8,9,10	Prefers dense shrubs in forest openings or under pole-sized trees for food and cover. Uses downed logs for cover and nest sites.	Temporarily eliminated from severe burns. Populations may increase dramatically as shrubs resprout and dominate the area. Will continue to use many less than severe burns.
White-tailed jackrabbit *L. townsendi*	7,8,9,10	Prefers early grass-forb successional stages.	May increase where fire removes overstory and creates meadow-type habitat.

(con.)

Table 4 (Con.)

Species	Fire Group(s)	Habitat considerations	Fire effects
RODENTIA (gnawing mammals):			
Least chipmunk *Eutamias minimus*	7,8,9,10	Present in high mountain coniferous forests. Requires open areas with stumps, downed logs, and shrubs or other high vegetation for cover.	Temporarily decreases following severe fire that reduces cover. Returns first season after fire and usually abundant by third postfire year.
Redtail chipmunk *E. ruficaudus*	2,3,7,8,9,10	Most common in forest openings or edges with abundant shrub undergrowth.	May be temporarily reduced or eliminated on severe burns lacking cover. Use of moderate burns may continue at reduced level, especially if cover and fresh seed is abundant. Populations may exceed preburn levels by second or third postfire year.
Yellow pine chipmunk *E. amoenus*	All	Prefers shrub, seedling, and sapling stages of forest succession. Usually abundant in open ponderosa pine forests and edges. Needs shelter of downed logs, debris, or shrubs. Often burrows under downed logs and stumps.	Recent burns with stumps and shrubs are favored habitat, especially as seed and fruit-producing annuals become available.
Yellow-bellied marmot *Marmota flaviventris*	All	Prefers rocky outcrops or talus slopes, forest openings up through spruce-fir zone. Uses downed logs for cover; burrows under tree roots. Feeds on green grass and forbs.	Relatively impervious to fire. Benefits from fire-created openings dominated by grass and forbs.
Hoary marmot *M. caligata*	7,8,9,10	Found in alpine and subalpine habitats; on talus slopes near grassy alpine meadows.	Relatively impervious to fire. Benefits from fire-created grassy openings.
Uinta ground squirrel *Citellus armatus*	7,8,9,10	Prefers moist habitats with lush vegetation and soft soil; subalpine meadows; forest edges.	May increase dramatically on areas where fire has killed overstory; may be favored by increased light and temperature as well as increase in herbaceous growth.
Belding ground squirrel *C. beldingi*	2,3,4,5,6	Generally restricted to mountain meadows and early successional stages in ponderosa pine, lodgepole pine, and Douglas-fir forests. Nests underground; requires friable soil. Feeds on grasses, forbs, seeds, bulbs, etc.	Benefits from fire-created openings that produce abundant herbaceous undergrowth.
Columbian ground squirrel *C. columbianus*	1,2,4,5,6	Prefers subalpine meadows, forest edges, open woodlands, pine flats, and alpine tundra. Uses downed logs for cover. Burrows on rocky, partly forested gentle slopes.	May increase on areas where canopy has been opened by fire, especially if grass, forbs, and seed are abundant.
Golden-mantled ground squirrel *C. lateralis*	All	Widespread from ponderosa pine forest to alpine meadows. Most abundant in open forests lacking a dense undergrowth or understory. Needs downed logs, stumps, or rocks for cover. Burrows for shelter.	Generally increases on recently burned areas due to increased abundance of forbs, providing adequate escape cover exists.
Red squirrel (pine squirrel) *Tamiasciurus hudsonicus*	All	Found in late successional forests. Nests in tree cavities and branches. Feeds on conifer seeds, nuts, bird eggs, fungi. Uses downed logs for cover.	Essentially eliminated following stand-replacing fires. Cavities in fire-killed trees may be used for dens but only if surrounded by live trees.
Northern flying squirrel *Glaucomys sabrinus*	2,3,4,5,6,7,8,9,10	Prefers a mature forest. Requires snags and trees with nest cavities. Also requires an abundance of downed logs. Feeds on conifer seed, serviceberries, and mushrooms.	Same as for red squirrel except may forage for fungi in recent burns.

(con.)

Table 4 (Con.)

Species	Fire Group(s)	Habitat considerations	Fire effects
Northern pocket gopher *Thomomys talpoides*	Wide range	Prefers disturbed areas of secondary vegetative growth; also pine forests, alpine parks, and meadows. Occurs mostly in deep sandy soils but also in clay and gravelly soils. Requires an herbaceous food source, especially annual forbs.	Population densities usually increase on areas burned by fires that open canopy and disturb the soil resulting in undergrowth of early successional forbs and grasses.
Beaver *Castor canadensis*	Wide range	Requires streams or lakes bordered by stands of aspen, alder, birch, poplars, or willow for food and building materials.	Usually increases following fires that initiate a successional sequence that includes aspen as an intermediate stage.
Western harvest mouse *Reithrodontomys megalotis*	Wide range	Generally restricted to grass-forb stages on all habitat types. Usually nests on ground but sometimes in woodpecker holes.	Generally favored by fires that result in establishment of seed-producing annual plants.
Deer mouse *Peromyscus maniculatus*	Wide range	Ubiquitous. Occurs in most successional stages of most habitat types. Nests in burrows, trees, and stumps. Uses downed logs for nesting sites and cover.	Populations reduce immediately following fire but significantly increase as soon as rain settles the ash. Most abundant small mammal on severely burned areas.
Bushy-tailed woodrat *Neotoma cinerea*	1,2,3,7,8,9 10	Prefers rocky situations. Dens in rock crevices; sometimes in hollow logs. Gathers conifer seed, berries, fungi, twigs, shoots, and green vegetation.	Relatively impervious to fires that occur in high-elevation rocky habitat. Usually not abundant on recent burns.
Southern red-backed mouse (boreal red-backed vole) *Clethrionomys gapperi*	All	Prefers mesic areas within coniferous forests that contain abundance of large debris on forest floor and undergrowth of shrubs and herbs. Feeds on conifer seed, bark, fungi, and green vegetation. A coniferous overhead tree canopy is preferred.	Usually eliminated from severely burned areas within 1 year after fire. If overstory trees are present and survive, favorable habitat may return in 7 or more years after the fire.
Mountain phenacomys (Heather vole) *Phenacomys intermedius*	All	Prefers open grassy areas and forest openings but also riparian zones. Nests under rocks, stumps, or other debris on forest floor. Often found in association with huckleberry.	Benefits from forest openings and early successional undergrowth that result from moderate to severe fires. Severe surface fires may destroy nesting habitat.
Meadow vole *Microtus pennsylvanicus*	1,2,3,7,8,9, 10	Requires a mat of ground cover for runways, palatable herbs, conifer seed, and moisture. Uses downed logs for cover and nest sites. Usually found near streamside.	Usually eliminated from severe burns where surface organic layer is absent. The wet nature of preferred habitat tends to resist fire.
Montane vole *M. montanus*	All	Habitat includes wet areas and mountain meadows within a relatively broad elevational range. Forages on ground for succulent stems and leaves of grasses and forbs. Constructs underground burrows.	Benefits from fire-created openings that support an undergrowth of grasses, sedges, and other wet site forbs.
Longtail vole *M. longicaudus*	2,3,7,8,9,10	Widespread in wet mountain meadows and forest edge, often near streams. Requires a grass-sedge-forb food source. Less restricted to runways and dense grass than other *Microtus*.	Use increases with removal of tree canopy especially on moist north slopes.
Water vole *Arvicola richardsoni*	7,8,9,10	Restricted to alpine marshes, willow-lined stream banks, and grass and sedge areas of the alpine and subalpine forests. Nests under roots, stumps, and logs.	Relatively impervious to fire. Severe fire that removes streamside cover may result in temporary loss of habitat.
Muskrat *Ondatra zibethicus*	Wide range	Occupies cattail marshes, banks of ponds, lakes, or slow-moving streams. Requires a source of succulent grasses or sedges, or other aquatic vegetation.	Periodic fire retains marshes in a subclimax state and removes unfavorable vegetation that crowds out useful plants.

(con.)

Table 4 (Con.)

Species	Fire Group(s)	Habitat considerations	Fire effects
Western jumping mouse *Zapus princeps*	All	Requires a well-developed extensive herbaceous layer along edge of rivers, streams, lakes, or other wet areas and moist soil. Uses downed logs for cover and nest sites. Eats seed, grass, and forbs.	Generally eliminated from severe burns that lack the required vegetative cover.
Porcupine *Erethizon dorsatum*	7,8,9,10	Prefers medium and old-age conifer stands of less than 70 percent crown closure and containing shrubs and herbs. Uses hollow logs and tree cavities for dens.	Use of severely burned areas curtailed especially if overstory is killed. May continue to use light and moderate burns.
CARNIVORA (flesh-eaters):			
Coyote *Canis latrans*	Wide range	Widespread occurrence in most habitats and most successional stages. Uses hollow logs or stumps for dens. Preys on mice.	Increased use of burned areas that support abundant small mammal populations.
Gray wolf *C. lupus*	7,8,9,10	Highly adaptable but probably restricted to wilderness forests. Preys on other mammals.	Probable increased use of burned areas that support an abundant population of prey species.
Red fox *Vulpes valpes*	All	Prefers open areas in or near forest. Uses hollow stumps and logs for dens. Food includes berries, insects, birds, rodents, squirrels, rabbits, and other small mammals.	Benefits from fires that create favorable habitat for small mammal prey species, especially those that enhance snowshoe hare populations.
Black bear *Ursus americanus*	Wide range	Prefers mature forests mixed with shrubfields and meadows. Omnivorous. Requires windfalls, excavated holes, or uprooted or hollow trees for den sites.	Benefits from abundant regeneration of berry-producing shrubs following fire. Severe fires may destroy favorable den sites.
Grizzly bear *U. horribilis*	Wide range	Uses all available habitat but prefers early successional stages for feeding and mature forest for cover. Occurrence is increasingly restricted to wilderness-type lands.	Seral forest communities maintained by fire are important for preferred berry-producing plants.
Raccoon *Procyon lotor*	Wide range	Very adaptable to environmental change; in riparian situations; along marshes, streams, and lakes. Uses hollow trees and downed logs for dens. Omnivorous.	Relatively impervious to fire because of mobility and wide ecological amplitude.
Marten *Martes americana*	2,3,4,5,6,7, 8,9,10	A forest dweller; requires relatively dense climax or near-climax situation. Uses tree or snag cavities and hollow stumps for nest sites. Food includes tree squirrels, chipmunks, mice, berries, insects.	Eliminated from severely burned stands. Benefits from vegetative mosaics resulting from periodic small fires because of increased food supply. Burns containing adequate cover may be used for feeding during summer and fall.
Fisher *M. pennanti*	2,3,4,5,6,7, 8,9,10	Prefers forest of large trees with many windfalls and downed logs. Nests in tree holes, hollow logs, and snags. Eats squirrels, porcupines, woodrats, mice, rabbits, insects, and berries.	Preferred habitat is adversely affected by severe fire. Benefits from increase in prey species on burns adjacent to favorable habitat. Adapts better to early successional stages than marten.
Ermine (shorttail weasel) *Mustela erminea*	2,3,4,5,6,7, 8,9,10	Prefers mature dense forest for breeding and resting; meadows or other forest openings for hunting. Dens often located in hollow logs and snags. Voles are an important prey; also mice, shrews, and chipmunks.	Adversely affected by severe fire that removes ground debris or kills overstory trees. Benefits from increased biomass of prey species that usually results on fire-created grass-forb successional stages.
Longtail weasel *M. frenata*	Wide range	Ubiquitous—common in most habitats. Prefers open areas and young pole stands. Den sites include logs, stumps, and snags. A major predator of voles and mice. Also feeds on gophers, chipmunks, birds, insects, and vegetation.	Benefits from increased biomass of prey species that usually results on recently burned areas.

(con.)

Table 4 (Con.)

Species	Fire Group(s)	Habitat considerations	Fire effects
Mink *M. vison*	Wide range	May occur in any habitat containing fish-supporting marshes, lakes, and streams. Hollow logs and tree stumps along streams may be used for den sites.	Relatively impervious to most fires. May be adversely affected where fire removes streamside cover and debris.
Badger *Taxidea taxus*	Wide range	Grass-forb stages of conifer forest succession is a preferred habitat. Likes **deep**, friable soil for burrowing and rodent capturing.	Benefits from fires that result in grass-forb successional stages because of the abundant rodent populations that are often present.
Striped skunk *Mephitis mephitis*	Wide range	Prefers early successional stages of forest but may be found in all stages and cover types. Uses hollow logs, stumps, and snags for den sites. Food includes large insects and small rodents.	Relatively impervious to fire. Benefits from increased biomass of prey species that usually occur on severe burns.
River otter *Lutra canadensis*	Wide range	Occurs along streams, marshes, and lakes. Dens in bank. Aquatic.	Essentially impervious to fire. Severe fires may destroy essential escape cover along streams, thereby adversely affecting use.
Mountain lion (cougar, puma) *Felis concolor*	4,5,6,7,8,9, 10	Found throughout all habitat types and successional stages. Highly mobile. Hunts deer, hares, rodents, and porcupines.	Often flourishes on recently burned areas due to increased prey availability.
Lynx *Lynx canadensis*	7,8,9,10	Primarily in dense coniferous forests at higher elevations. May den in hollow logs. Snowshoe hare is an important prey species.	Benefits from fire-initiated shrub stages of succession that support large populations of snowshoe hare.
Bobcat *L. rufus*	Wide range	Found in most habitats and successional stages; shrub-sapling stages being especially desirable. May establish den under large logs or in hollow logs. Preys on rodents, reptiles, and invertebrates.	Relatively impervious to fire. Benefits from any fire-induced increase in availability of prey species.
ARTIODACTYLA (even-hoofed mammals):			
Elk *Cervus canadensis*	4,5,6,7,8,9, 10	Prefers semiopen forest but with areas of dense cover for shelter. Requires food supply of grass, forbs, and shrubs, especially Scouler willow, maple, serviceberry, redstem, and chokecherry.	Severe burns usually experience a decline in first-year use; then an increase as preferred browse species become available. Moderate fires in forest may remove ground debris and other obstructions to movement.
Mule deer *Odocoileus hemionus*	Wide range	Occupies a wide range of habitats including open montane and subalpine coniferous forest; forest edges, woodlands, and shrubfields. Shrub-seedling-sapling stage of succession preferred. Needs trees and shrubs for cover on winter range. Preferred food includes tender new growth of palatable shrubs—ceanothus, cherry, mountain-mahogany, bitterbrush; many forbs and some grasses.	Fire may improve winter nutrition in grassland and mountain shrub communities by increasing the amount of green grasses. Often a decline in use during first postburn year and then an increase in subsequent years. Where antelope bitterbrush is an important winter range species, moderate to severe fires may be detrimental.
Whitetail deer *O. virginianus*	All	Prefers dense forest; rough, open shrublands; thickets along streams and woodlands. Diet includes shrubs, twigs, fungi, grasses, and forbs.	Fire-initiated early successional stages supporting new growth of grasses, forbs, and shrubs provide a preferred food source.
Moose *Alces alces*	All	Prefers subclimax forests with lakes and swamps. Ideal habitat includes a mosaic of numerous age classes and distribution of aspen and associated trees and shrubs within the wintering range.	Fires that result in abundant aspen and willow regeneration create a preferred habitat. Optimal successional stage occurs from 11 to 30 years following a severe fire.
Mountain goat *Oreomnos americanus*	7,8,9,10	Frequents alpine and high subalpine zones; on steep slopes. Feeds on grasses, sedges, and shrubs.	Relatively impervious to fire; usually above fire-prone forest areas. Fire that sweeps up through subalpine and alpine forests may create favorable goat range.

(con.)

Table 4 (Con.)

Species	Fire Group(s)	Habitat considerations	Fire effects
Bighorn sheep (mountain sheep) *Ovis canadensis*	7,8,9,10	Preferred habitat characterized by rugged rocky mountain slopes with sparse trees and adjacent to alpine meadows. Feeds on alpine shrubs and forbs in summer; shrubs and perennial grasses in winter.	Canopy removal by fire may yield increased productivity of undergrowth and makes available more open habitat thereby dispersing populations and reducing incidence of lungworm infections. Fire may retard successional advance of alpine grasslands and improve productivity and palatability of important forage species. Fire can improve nutrition in mountain shrublands by increasing availability of green grass.
CAUDATA (salamanders):			
Long-toed salamander *Ambystoma macrodactylum*	All	Occupies a variety of habitats from sagebrush steppe to alpine meadows. Requires ponds or lakes for breeding. Found in rotting logs, under bark and other debris surrounding quiet waters.	Adversely affected by severe fires that remove lake- or pond-side debris; otherwise relatively impervious to most fires.
Tiger salamander *A. tigrinum*	2,4,5,6,7,8, 9,10	Found in and near pools, ponds, lakes, and streams. Adults sometimes burrow in decayed logs in damp forest situations.	Impervious to fire except for minor direct mortality in severe fire situations.
SALIENTIA (frogs and toads):			
Bullfrog *Rana catesbeiana*	Wide range	Inhabits lakes, marshes, pools, ponds, reservoirs, and streams. Hides under debris at water's edge.	Relatively impervious to fire.
Spotted frog *R. pretiosa*	All	Highly aquatic.	Impervious to fire.
Leopard frog *R. pipiens*	Wide range	Stays around water. In summer it inhabits swamps, grassy woodland or short grass meadows.	Generally impervious to fire. Some direct mortality possible from fast-spreading surface fire.
Pacific tree frog *Hyla regilla*	All	Varied habitats. It may inhabit damp recesses among rocks and logs in damp woodland or forest. Uses downed logs for hiding and thermal cover.	Damp habitat minimizes fire effects. Surface fire under severe drying conditions could degrade habitat.
Chorus frog *Pseudacris triseriata*	7,8,9,10	Occupies high grasslands and mountain forests. Inhabits marshes, meadows, lake margins, and grassy pools. Usually found on the ground or in low plants.	Relatively impervious to fire because of wet habitat.
Boreal toad (western toad) *Bufo boreas*	All	Found in or near water. Burrows in loose soil.	Relatively impervious to fire.
SQUAMATA (snakes and lizards):			
Western skink *Eumeces skiltonianus*	1,2,4,5,6	Found in woodland and forest with dense vegetation. Inhabits rocky streamsides, dry grassy hillsides, forest openings, and meadows. Hides under logs and bark. Diet includes moths, beetles, crickets, grasshoppers, and spiders.	Severe surface fires will reduce cover and food supply.
Western whiptail *Cnemidophorus tigris*	1,2,3	Found in openings; avoids dense vegetation. Prefers open woodlands and warmer parts of the forest.	Severe fire may result in some direct mortality. Generally benefits from fire-created openings within its range.
Rubber boa (Rocky Mountain boa) *Charina bottae*	All	Found near streams and meadows in all forest types; prefers pole to mature stands. Uses rotting logs, and bark of fallen and standing dead trees for hiding. Feeds on rodents, insects, and lizards on forest floor.	Severe surface fire can remove cover and temporarily reduce abundance of prey species.

(con.)

Table 4 (Con.)

Species	Fire Group(s)	Habitat considerations	Fire effects
Racer (western yellow-bellied racer) *Coluber constrictor*	1,2,3	Inhabits open woodlands, wooded ravines, and thickets. Diet includes lizards, frogs, small rodents, snakes, and insects.	Surface fire may adversely affect food supply.
Gopher snake (bullsnake) *Pituophis melanoleucus*	1,2,4,5,6	Highly adaptable species; occupies a variety of habitats. Mainly hunts on surface for small mammals.	Relatively imperivous to fire because of wide ecological amplitude.
Common garter snake (red-sided garter snake; valley garter snake) *Thamnophis sirtalis*	All	Widely distributed in many different habitats which include a water source. Diet largely aquatic but includes small mammals.	Impervious to fire.
Western terrestrial garter snake *T. elegans*	Wide range	Found in all successional stages of all habitat types near permanent or intermittent streams and ponds.	Relatively impervious to fire because of its tendency to be close to water.
Western rattlesnake (prairie rattlesnake) *Crotalus viridis*	1,2,3,4,5,6	Highly variable habitats, including open woodlands to mountain forests. Often found in rock outcrops. Hunts on surface for rodents.	Relatively impervious to fire except for possible direct mortality in severe surface fire situations.

Table 5—Hypothesized fire tolerance for some central Idaho birds (adapted from Kramp and others 1983)[1]

Fire intolerant	Fire impervious	Fire adapted	Fire dependent
Ash-throated flycatcher	Common crow	American kestrel	Blue grouse
Bewick's wren	Robin	Robin	House wren
Black-capped chickadee*	Black-billed magpie	Black-headed grosbeak	Mourning dove
Black-throated gray warbler	Black vulture	Blue grosbeak	Sandhill crane
Brewer's sparrow	Blue-winged teal	Blue-winged teal	Turkey
Brown creeper	Brown-headed cowbird	Brewer's sparrow	
Burrowing owl	Canadian goose	Canadian goose	
Common bushtit	Cedar waxwing	Cassin's kingbird	
Cassin's finch*	Chestnut-collared longspur	Clark's nutcracker	
Chipping sparrow	Clark's nutcracker	Cliff swallow	
Golden-crowned kinglet	Cliff swallow	Common flicker	
Grasshopper sparrow	Common flicker	Common nighthawk	
Great horned owl*	Common raven	Cooper's hawk	
Hammond's flycatcher	Common snipe	Dark-eyed junco	
Hermit thrush	Eastern kingbird	Downy woodpecker	
Mountain chickadee*	European starling	Eastern bluebird	
Goshawk*	Gadwall	Eastern meadowlark	
Northern harrier*	Great blue heron	Fox sparrow	
Pine siskin	Horned lark	Gadwall	
Pygmy nuthatch	Lark bunting	Gambel's quail	
Red-breasted nuthatch*	Loggerhead shrike	Green-tailed towhee	
Red crossbill	MacGillivray's warbler	Hairy woodpecker	
Ruby-crowned kinglet	Mallard	House wren	
Rufous-sided towhee*	Mourning dove	Killdeer	
Sharp-shinned hawk*	Northern pintail	Lark sparrow	
Solitary vireo	Orchard oriole	Lazuli bunting	
Western flycatcher	Red-winged blackbird	Mallard	
Western tanager*	Snowy egret	Mountain bluebird	
White-crowned sparrow*	Song sparrow	Northern harrier	
White-throated sparrow	Steller's jay	Northern pintail	
Yellow-rumped warbler*	Townsend's solitaire	Poor-will	
Yellow warbler	Turkey vulture	Rufous-sided towhee	
		Savannah sparrow	
		Screech owl	
		Snowy egret	
		Three-toed woodpecker	
		Tree swallow	
		Vaux's swift	
		Vesper sparrow	
		Violet-green swallow	
		Western bluebird	
		Western kingbird	
		Western meadowlark	
		Western woodpewee	
		Wild turkey	
		Williamson's sapsucker	
		Winter wren	
		Yellow-bellied sapsucker	

---

*Breeding cover negatively impacted by fire, foraging use made of burned areas.

[1] Caution is urged in using this table. Assignment of a species to one or more categories is based, in most cases, on limited data and opinion. Definitions in the text for each category should be read carefully.

FIRE USE CONSIDERATIONS

The management implications of fire ecology information are presented at the end of each fire group discussion. The use of fire to accomplish certain resource management objectives is suggested. The following fire use considerations apply generally to all Fire Groups. They are presented here to avoid repetition.

Heat Effects and Insect Attack

Care must be taken when burning in forest stands to prevent or minimize scorching the crowns of residual overstory trees. Heavy fuel accumulations or slash concentrated near the base of overstory trees may require scattering or other treatment to avoid lethal cambium heating. Excessive crown scorch, cambium, damage or both can result in loss of vigor and increased susceptibility to bark beetle attack or tree mortality. For example, the relationships between crown defoliation and mortality caused by the western pine beetle (*Dendroctonus brevicomis*) in ponderosa pine has been generalized as follows (Stevens and Hall 1960):

Percent defoliation	Percent of trees killed by beetles
0-25	0-15
25-50	13-14
50-75	19-42
75-100	45-87

The season in which a fire occurs is an important factor influencing direct tree mortality, and the subsequent occurrence, duration, and severity of a beetle attack. The result of crown scorching is usually more severe during the active growth period early in the summer than later when growth has slowed, terminal buds have formed, and a food reserve is being accumulated (Wagener 1955, 1961). Likewise, crown scorching that occurs in early spring, before or immediately after bud burst, often results in minimum damage to the tree.

Understory vegetation and dead surface fuels can be burned without serious threat of subsequent damage by bark beetles if the overstory trees are not severely scorched (Fischer 1980; Safay 1981). If accidental scorching does occur, and bark beetle activity is detected, prompt removal of the severely scorched trees will reduce the probability of subsequent damage to healthy green trees. If scorching occurs outside the active growth period, scorched trees may recover and regain lost vigor. This may take 3 years, but signs of recovery should be visible during the first growing season that follows scorching.

Frequency of Burning

The effects of repeated burning on a given site are not well defined for central Idaho forests. Consequently, it seems prudent to follow the wildfire frequencies that existed prior to organized fire suppression (Arno 1976). Too frequent fire might result in loss of seed source, loss of nutrients, and a decline in the fertility of the site.

Large Woody Debris

An important consideration is the retention of enough woody material to maintain forest site quality. The relationships between organic matter and ectomycorrhizae in Intermountain Region forest soils have been described by Harvey and others (1981) and by Harvey (1982). They found ectomycorrhizal development was stimulated by the presence of decayed wood in the soil. Decayed wood also contributes moisture and nutrients that favor continued seedling growth. These potential benefits are especially important on moderately dry sites.

Scattered large logs left on a site also retard soil movement and provide shade for young seedlings. The more tolerant tree species, such as subalpine fir or Engelmann spruce, will not successfully regenerate without at least partial shade. Harvey and others (1981) suggest that about 11 to 17 tons/acre (2.5 to 3.8 kg/m^2) of fresh residues larger than 6 inches (15 cm) in diameter should be left on the site following logging and burning. In addition, only as much mineral soil should be bared as is necessary to obtain desired stocking. Amounts of organic matter in excess of the above requirements can be considered undesirable especially on dry sites. Excess buildup of fuels can set the stage for high-intensity wildfires that result in an extreme reduction of the soil's organic reserves. Numerical relationships for predicting duff and woody fuel consumption by prescribed fire in the Intermountain area are provided by Brown and others (1985).

A final reason for leaving moderate amounts of large-diameter woody debris scattered on the site following logging and burning is to supply food and cover for wildlife. Many small mammals that reside in central Idaho forests rely on forest floor debris for cover and nesting sites. Rotten logs are often important foraging sites for both mammals and birds. Logs, for example, are important feeding sites for pileated woodpeckers.

Woodpeckers and other cavity-nesting birds (and mammals) also require snags, preferably scattered patches of snags, for nesting sites (McClelland and Frissell 1975; McClelland and others 1979).

The need to retain moderate amounts of scattered large-diameter woody debris should not preclude slash disposal. Unabated logging slash represents a significant fire hazard on most sites, usually greatly in excess of the pretreatment situation. This increased hazard will exist for at least 3 to 5 years, even with a maximum compaction effect from winter snows.

Unabated logging slash as well as large accumulations of deadfall in untreated stands can affect elk behavior and movement. Elk use may be diminished when slash inside a treatment unit, or when dead and down material outside, exceeds 1.5 feet (0.5 m) in depth (Boss and others 1983).

Heat Effects on Soil

Properly applied, prescribed fire has a low risk of causing long-term adverse effects on the fertility of the most common central Idaho soils. The effect on naturally infertile soils as in the Idaho batholith is, however, unclear and should be monitored. The shallow, granitic soils of the

Idaho batholith, including the Salmon Uplands and Southern Batholith physiographic regions, tend to be very erodible (Gonsior and Gardner 1971; Megahan 1974; Clayton and others 1979). The presence of living vegetation, especially trees and tree roots, is important to soil stability, hence a severe fire can increase erosion and the possibility of landslides and other mass soil movement (Gonsior and Gardner 1971; Megahan and others 1978; Megahan 1983). The intense heat and ashes resulting from burning bulldozer-piled slash can affect regeneration success on the area occupied by the piles. Size of piles should, consequently, be kept small and burning should be deferred to periods of relatively high fuel and soil moisture (Holdorf 1982).

Prescribed Fire Planning

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. Successful prescribed burning requires planning. Such planning should be based on the following factors (Fischer 1978):

1. Physical and biological characteristics of the site to be treated.
2. Land and resource management objectives for the site to be treated.
3. Known relationships between preburn environmental factors, expected fire behavior, and probable fire effects.
4. The existing art and science of applying fire to a site.
5. Previous experience from similar treatments on similar sites.

FIRE GROUP ZERO: MISCELLANEOUS SPECIAL HABITATS

Group Zero is a miscellaneous collection of habitats that have fire ecology and management implications, but that do not fit into the central Idaho habitat type classifications.

Scree

The term "scree" refers to slopes covered with loose rock fragments, usually lying almost exactly at the maximum possible angle of repose so that any disturbance causes miniature rock slides down the face of the slope. Scree slopes may be treeless or they may support scattered trees with sparse undergrowth. Usually scree communities are regarded as special environments where the vegetation is in an uneasy equilibrium with the unstable substrate.

The trees most often associated with scree at lower elevations are ponderosa pine, limber pine, and Douglas-ir. At higher elevations, these habitats are occupied by odgepole pine, Engelmann spruce, subalpine fir, or whitebark pine.

The discontinuous fuel often makes scree slopes unburnble. Individual trees or islands of vegetation may ignite, ut fire spread is limited. A severe, wind-driven fire could pass over the intervening open spaces and destroy a scree ommunity, but this rarely happens. In subalpine fir communities it is not unusual for a fire to spread from tree to tree aided by firebrands created when a subalpine fir crown torches-out. Due to the harsh environment, scree sites revegetate slowly.

Forested Rock

Forested rock is usually a very steep canyon wall or mountain side composed of rock outcrops, cliffs, and occasional clumps of trees clinging to ledges and crevices. Forested rock is especially prominent along the canyons of major rivers and in rugged upper subalpine areas near timberline. These sites bear a certain similarity to scree sites, but the substrate is relatively stable and climax vegetation frequently become established.

Surface fires do not burn well because of the vertical and horizontal discontinuity of ground fuels. The probability of crown fires depends on the density and arrangement of trees on the rock face. In some cases the islands of vegetation are so widely scattered as to be almost immune to wildfire. In other cases, particularly in low-elevation Douglas-fir-forested rock communities, unbroken foliage may extend from the base to the top of a cliff. Each tree forms a ladder into the lower branches of the next higher tree upslope. In such cases crown fires can occur over ground that would not support a less severe surface fire.

Revegetation of rocky sites depends on the severity of the fire, the characteristics and availability of soil, and the availability of a seed source.

Wet Meadow

A meadow is an opening in the forest that is characterized by herbaceous vegetation and abundant water. Subirrigation is common during at least some part of the growing season. Mountain meadows are frequently too wet to burn during the fire season. In midsummer, wet meadows often act as natural firebreaks, but during the late summer and early fall they may carry grass fires.

It is the nature of streamside meadows to gradually become drier in the course of primary succession, from the hydric to the mesic condition. The buildup of organic material and trapped sediments from the flowing water, combined with a possible deepening of the stream bed and lowering of the water table, can leave former meadows in an intermediate condition between wet meadow and grassland. In some such sites the meadow becomes bordered by fire-maintained grassland. Fire suppression has allowed conifers to invade meadows where they would not normally be found.

Mountain Grassland

A mountain grassland is a grass-covered opening within an otherwise continuous coniferous forest. Mountain grasslands may act as firebreaks and can be maintained as grassland by light fires, but usually their fire ecology is less obvious. Despain (1973), working in the Bighorn Mountains of Wyoming, found stable boundaries between grassland and forest, and theorized that topoedaphic factors may produce parks. Daubenmire (1943) suggested that edaphic factors might cause permanent parks.

Langenheim (1962), in west-central Colorado, speculated that grasslands dominated by Thurber fescue might be relicts from a warmer and drier period during the Pleistocene. Caution is indicated in management of stands adjacent to mountain grasslands until conditions responsible for their perpetuation are determined.

Aspen Communities

Aspen communities dominate a variety of sites in central Idaho. Aspen stands that appear below the elevational limits of conifers may be climax. More often aspen is a seral species although it may persist for long periods.

An aspen clone is long-lived and consists of many individual stems produced on a system of lateral roots. The individual stems (suckers or ramets) are not fire resistant, but the clone is fire resistant, sending up new suckers following fires. Fire may rejuvenate deteriorating stands and may be necessary to promote sufficient suckering to maintain aspen in areas where it is seral (DeByle and others in press).

Deciduous Riparian Communities

Riparian, flood plain, and ravine communities are typified by various species of cottonwood, birch, willow, dogwood, hawthorn, alder, and sedge. Although the species composition of these communities varies throughout the region, the communities are easily recognizable as wet sites dominated by deciduous species; conifers either are scarce or entirely absent. Wet-site, spruce-dominated communities are included in Fire Group Nine.

Under normal moisture conditions, riparian areas frequently may act as firebreaks. They can, however, burn severely when dry especially early in the spring after snowmelt and before green-up, or late in the fall. Many of the deciduous species found on these wet sites resprout following fire, and some of these, for example, alder, put up several new sprouts for each burned plant, thus increasing the stand's density.

The ecology of these communities is dominated by the predictable disturbances caused by floods and the fluctuations in stream course, water tables, soil depth, and soil particle-size distribution and organic matter accumulation that follow such flooding.

Fire Management Considerations

Group Zero sites burn poorly under normal summer weather conditions. Fire managers can take advantage of this fact when developing preattack plans and when delineating fire management areas, units, or zones. These sites can also serve as anchor points for fuel breaks and firebreaks.

Meadows, aspen communities, and riparian zones can be important wildlife habitats. Prescribed fire is often a suitable tool for maintaining desired forage conditions on these sites.

FIRE GROUP ONE: DRY LIMBER PINE HABITAT TYPES

ADP code	Habitat type-phase (Steele and others 1981)	Physiographic sections (Steele and others 1981
080	*Pinus flexilis/Hesperochloa kingii* h.t. (PIFL/HEKI), limber pine/spikefescue	Open Northern Rockies
050	*Pinus flexilis/Festuca idahoensis* h.t. (PIFL/FEID), limber pine/ Idaho fescue	Open Northern Rockies
060	*Pinus flexilis/Cercocarpus ledifolius* h.t. (PIFL/CELE), limber pine/curlleaf mountain-mahogany	Open Northern Rockies
070	*Pinus flexilis/Juniperus communis* h.t. (PIFL/JUCO), limber pine/ common juniper	Open Northern Rockies

Vegetation

Limber pine occurs primarily as an incidental forest ty in the Open Northern Rockies section of central Idaho (Steele and others 1981). It occupies the driest forest sites—below the lower limits of Douglas-fir forests or on exposed rocky sites within the Douglas-fir zone (Steele a others 1981). Limber pine may either be the only tree species on the site, or codominant with Douglas-fir. Rock Mountain juniper is a minor climax associate on some limber pine sites.

Spikefescue and bluebunch wheatgrass are primary undergrowth species on harsh sites. Idaho fescue and mountain big sagebrush may be conspicuous on less than severe sites. Curlleaf mountain-mahogany, creeping barberry, mountain snowberry, common juniper, and weedy milkvetch occur with varying frequencies.

Forest Fuels

Downed, dead woody fuels are rarely a fire hazard in Group One stands. In eastern Montana, for example, fuel loads range between 5 and 15 tons/acre (l and 3.4 kg/m^2) on limber pine habitat types (Fischer and Clayton 1983; Brown and See 1981). About 80 percent or more of the downed woody fuel is 3 inches (7.6 cm) in diameter or larger. This material is often the result of fallen snags created by a previous fire. Such material is usually scattered about the site (fig. 3). Hazardous fuel conditions ar often the result of dead herbaceous fuels.

Role of Fire

Fire history information for central Idaho limber pine sites is lacking. Arno and Gruell (1983) determined a mean fire interval (MFI) of 74 years within the PIFL/AGSP h.t. in southwestern Montana. This MFI may overestimate the average time between fires at a given point on the ground because fuels are so light that the trees may not be well scarred by fire (Arno and Gruell 1983).

Cooper (1975) found a number of 300-year-old Douglas-fir with four to six fire scars each on a PIFL/HEKI h.t. in northwestern Wyoming.

Limber pine invasion of adjacent grass and shrublands is a slow process. The fire-susceptibility of young limber pine and Douglas-fir would seem to preclude successful invasion of sites that experienced historical (pre-1900) grassland fire frequencies of 5 to 25 years. Successful invasion could occur, however, under a frequent fire regime of cool surface fires. Keown (1977) killed only 20 percent of the invading limber pines with low-severity prescribed fire in the spring; his severe fires killed 80 percent of the invaders.

Frequent low-intensity surface fires could favor development of limber pine stands by keeping fuels from reaching levels that would support severe tree-killing fires. The possibility that limber pine communities have burned frequently in the past with very slight effects (no scarring) cannot be ruled out. The existing evidence, however, suggests infrequent fires. The lack of continuous fuels, perhaps due in part to grazing, usually limits fire severity although occasional wind-driven crown fires can occur.

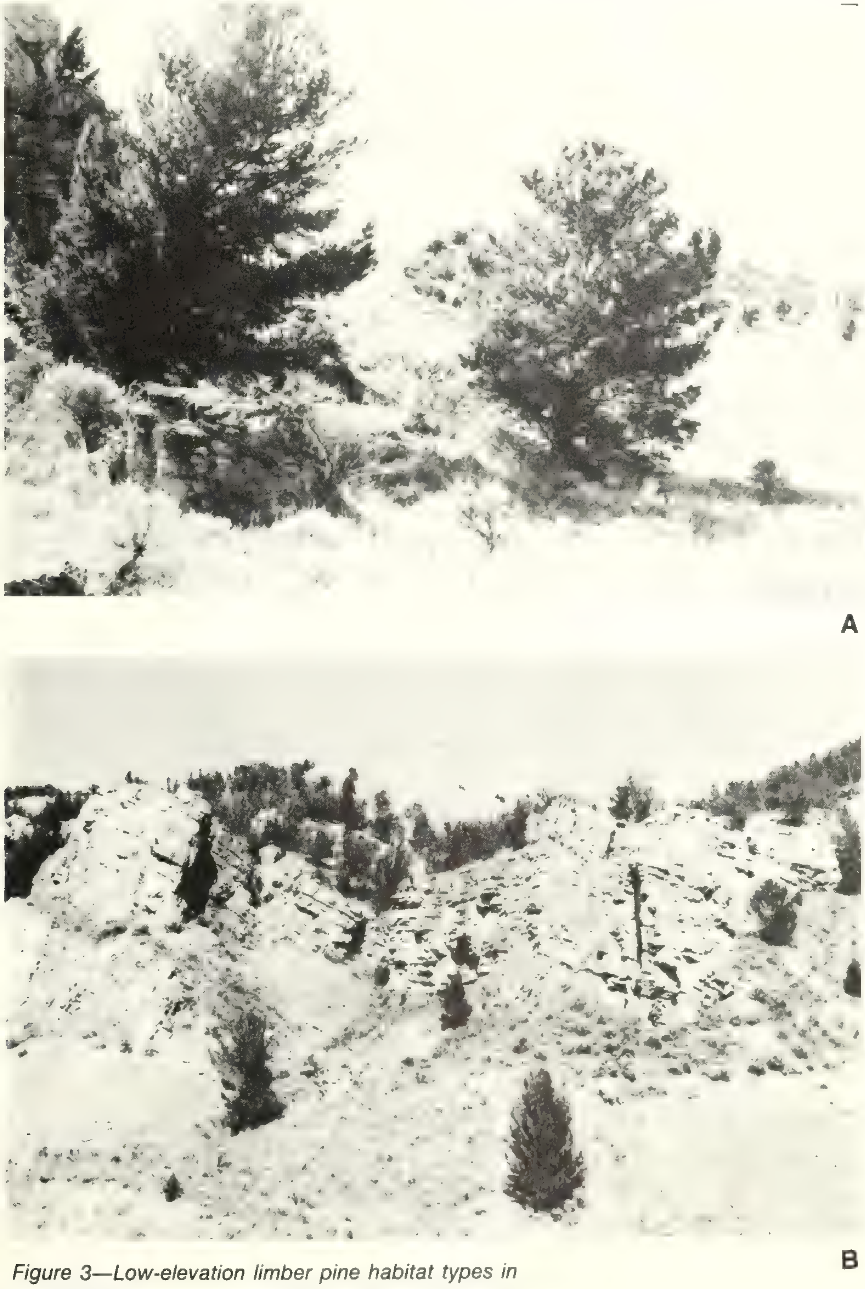


Figure 3—Low-elevation limber pine habitat types in Railroad Canyon, northeast of Leadore, ID, Salmon National Forest.

Forest Succession

A generalized concept of forest succession in Group One habitats and how fire affects this succession is shown in figure 4 (subsequent numbers in this section refer to fig. 4).

Grassland sites that are potential limber pine sites were probably maintained as grassland by frequent grass fires (No. 1). It is uncertain that this effect is taking place anywhere today; moreover, the frequency of fire required to prevent conifer invasion of the grassland is not known.

A shrub stage may develop within the PIFL/CELE and PIFL/JUCO h.t.'s. A thinning fire in the sapling stage could eliminate some shrubs (temporarily) and favor limber pine over Douglas-fir (No. 2). A severe fire (No. 3) at any stage can kill most of the trees and return grass to the site.

With a long, fire-free interval, the slow-growing trees will reach maturity and acquire some fire resistance due to a thickened bark. Light-to-moderate surface fires (if allowed to burn) would be most likely (No. 4) and would help maintain an open stand. If fire does not thin the mature forest over a very long period, then accumulating regeneration and litter can eventually contribute to a wind-driven, stand-destroying wildfire (No. 5). Such a fire would return the site to grassland.

Successional pathways based on the combined effects of fire, plant succession, and fire exclusion are hypothesized in figure 5.

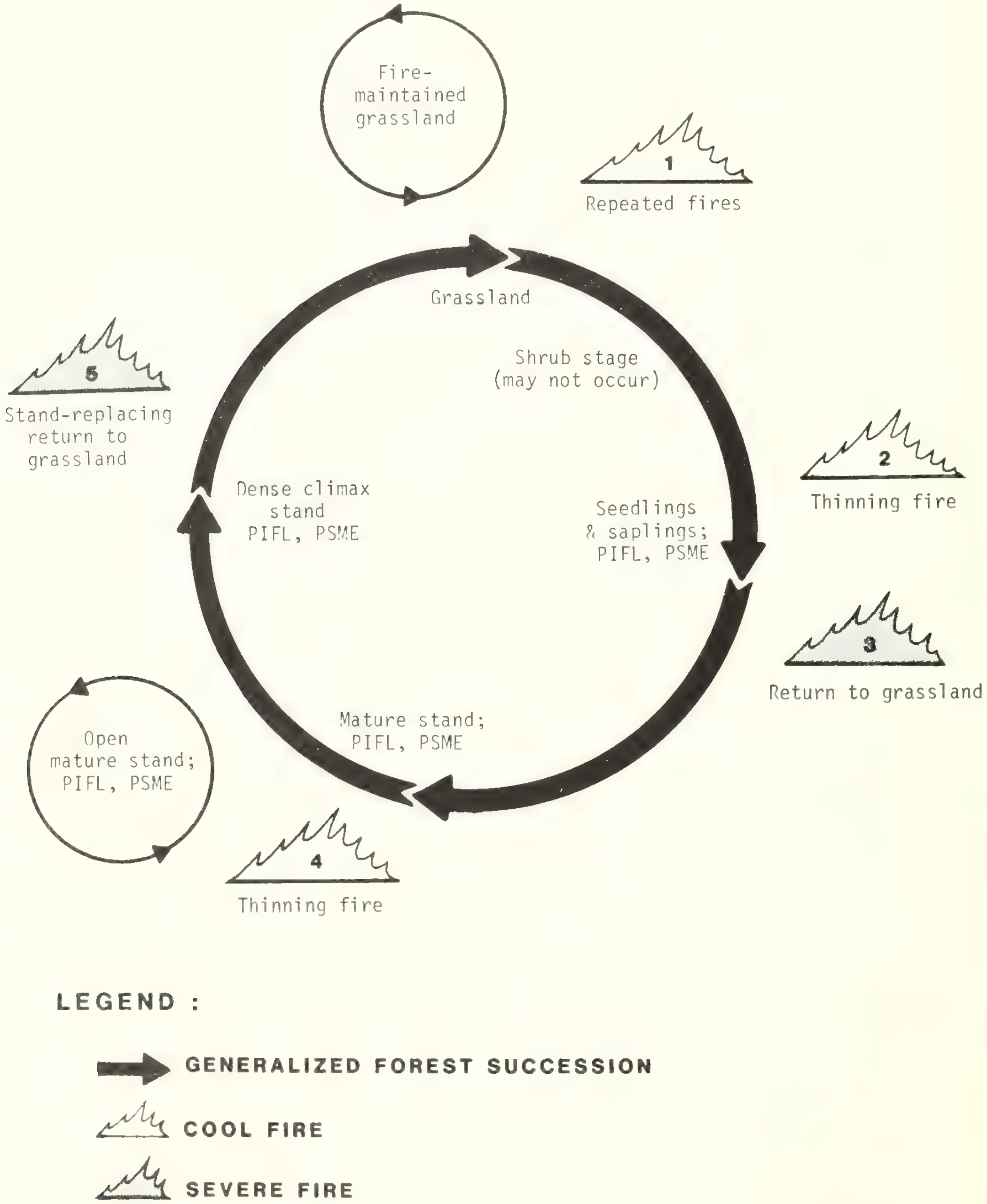
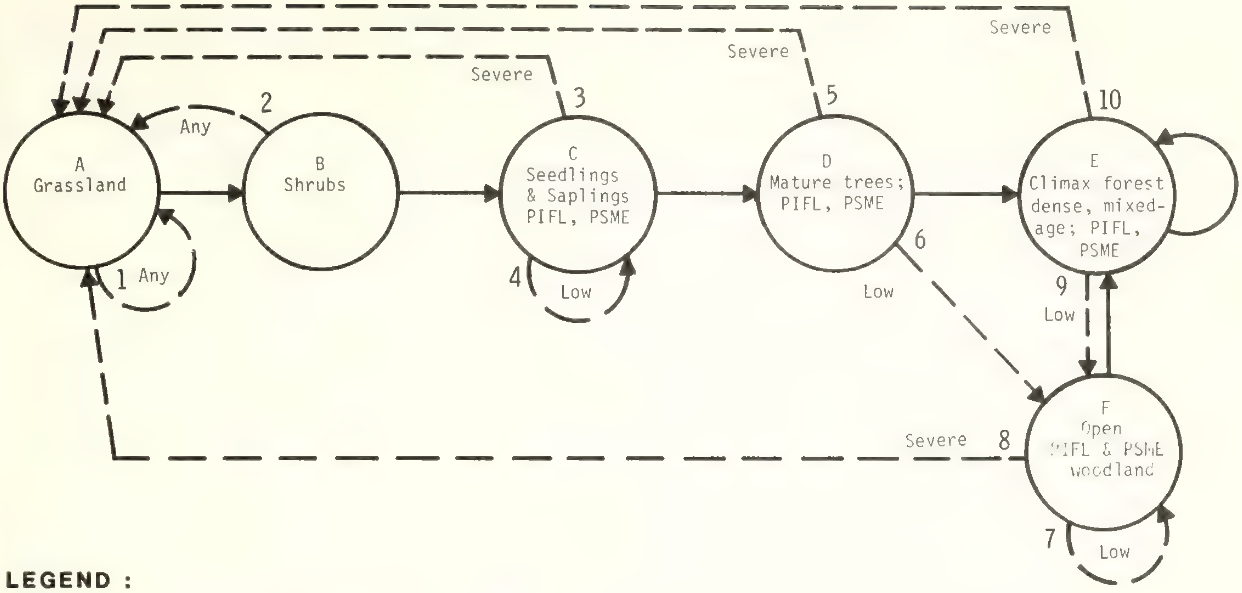

Fire-maintained grassland
1
Repeated fires
Grassland
Shrub stage (may not occur)
2
Thinning fire
Seedlings & saplings; PIFL, PSME
3
Return to grassland
Mature stand; PIFL, PSME
4
Thinning fire
Open mature stand; PIFL, PSME
Dense climax stand PIFL, PSME
5
Stand-replacing return to grassland
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 4—Generalized forest succession in Fire Group One: limber pine climax series habitat types.



LEGEND :

——▶ **SUCCESSION IN ABSENCE OF FIRE**
– – ▶ **RESPONSE TO FIRE**
LOW **COOL OR LIGHT SURFACE FIRE**
MOD. **FIRE OF MODERATE SEVERITY**
SEVERE **HOT STAND-REPLACEMENT FIRE**
1,2, etc. **REFERENCE NUMBER (SEE TEXT)**

Figure 5—Hypothetical fire-related successional pathways for Fire Group One habitat types.

Fire Management Considerations

Productivity of trees and undergrowth is usually low on limber pine sites. Consequently, high fire control expenditures are seldom justified unless life, private property, and adjoining high resource values are seriously threatened. Sparse surface fuels often limit fire spread in open stands. Such stands often serve as natural fuel breaks under most burning conditions. Severe fires can, however, seriously damage dense stands on steep, windswept slopes and ridges. Recovery on such sites will be slow.

Limber pine sites are most valuable as a source of food and cover for mule deer, elk, and bighorn sheep especially as winter range. Periodic surface fires can benefit browse and forage production for wildlife on some sites. Periodic fire can also check limber pine invasion of adjoining grasslands.

FIRE GROUP TWO: WARM, DRY HABITAT TYPES THAT SUPPORT OPEN FORESTS OF PONDEROSA PINE OR DOUGLAS-FIR

ADP code	Habitat type-phase (Steele and others 1981)	Physiographic sections (Steele and others 1981)
120	*Pinus ponderosa/Stipa occidentalis* h.t. (PIPO/STOC), ponderosa pine/western needlegrass	Southern Batholith
130	*Pinus ponderosa/Agropyron spicatum* h.t. (PIPO/AGSP), ponderosa pine/bluebunch wheatgrass	Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils
140	*Pinus ponderosa/Festuca idahoensis* h.t. (PIPO/FEID), ponderosa pine/Idaho fescue	Salmon Uplands, Southern Batholith, and Wallowa-Seven Devils
161	*Pinus ponderosa/Purshia tridentata* h.t. - *Agropyron spicatum* phase (PIPO/PUTR-AGSP), ponderosa pine/bitterbrush - bluebunch wheatgrass phase	Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils
162	*Pinus ponderosa/Purshia tridentata* h.t. - *Festuca idahoensis* phase (PIPO/PUTR-FEID), ponderosa pine/bitterbrush - Idaho fescue phase	Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils
195	*Pinus ponderosa/Symphoricarpos oreophilus* h.t. (PIPO/SYOR), ponderosa pine/mountain snowberry	Southern Batholith and Wallowa-Seven Devils
210	*Pseudotsuga menziesii/Agropyron spicatum* h.t. (PSME/AGSP), Douglas-fir/bluebunch wheatgrass	All sections

ADP code	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
221	*Pseudotsuga menziesii/Festuca idahoensis* h.t. - *Festuca idahoensis* phase (PSME/FEID-FEID), Douglas-fir/Idaho fescue - Idaho fescue phase	Challis and Open Northern Rockies
222	*Pseudotsuga menziesii/Festuca idahoensis* h.t. - *Pinus ponderosa* phase (PSME/FEID-PIPO), Douglas-fir/Idaho fescue - ponderosa pine phase	Salmon Uplands and Southern Batholith
380	*Pseudotsuga menziesii/ Symphoricarpos oreophilus* h.t. (PSME/SYOR), Douglas-fir/mountain snowberry	Open Northern Rockies, Challis, and Southern Batholith
385	*Pseudotsuga menziesii/ Cercocarpus ledifolius* h.t. (PSME/CELE), Douglas-fir/ curlleaf mountain-mahogany	Challis and Open Northern Rockies

Vegetation

Fire Group Two sites frequently border grasslands in central Idaho. Usually ponderosa pine and Douglas-fir are the only trees on the site, although aspen may be present as accidental individuals. Sites are frequently steep south- and west-facing slopes where a scarcity of soil moisture limits both establishment and growth rates of trees. Lower elevation ponderosa pine communities may occur on gentle terrain of varying aspect.

The fortuitous occurrence of a duff-consuming fire followed by a good seed crop and then adequate moisture can result in sporadic tree regeneration (Steele and others 1981). Good seed crops are infrequent.

Undergrowth is primarily composed of grass (fig. 6), although bitterbrush, big sagebrush, mountain snowberry, and curlleaf mountain-mahogany are major components on some sites. Common grass and forb species include bluebunch wheatgrass, Idaho fescue, western needlegrass, Wheeler's bluegrass, oniongrass, and arrowleaf balsamroot.

Forest Fuels

Downed, dead woody fuel loads are often light. The amount of material less than 3 inches (7.6 cm) in diameter rarely exceeds 5 tons/acre (1 kg/m^2). The amount of material greater than 3 inches (7.6 cm) varies according to stand age and condition, but generally accounts for nearly 70 percent or more of the total downed woody fuel load. Large downed fuels commonly result from competition in dense stands, fire, insects, or disease; and damage by wind, snow, or tree-felling, and logging residues.

Stands are generally characterized by discontinuous patches of deep to very deep needle mat layers. Often, most abundant surface fuel is dead, or curing grass. Th is especially true for mature, open-grown stands. Dow woody fuel in such stands usually consists of widely sc tered large deadfalls and concentrations of twigs, branchwood, and cones near the base of individual tree

Fuel loadings in stands infested with dwarf mistletoe can be considerably greater than in uninfested stands. Severely infested ponderosa pine stands in central Ore for example, contained significantly greater amounts o dead surface fuels of all size classes than did uninfeste less severely infested stands (Koonce 1981). Weir (1916 noted that large, dense witches'-brooms caused by dwa mistletoe in Douglas-fir are often broken from the trees during snowstorms and accumulate around the bases o the trees (Alexander and Hawksworth 1975). The prese of witches'-brooms in the crowns of ponderosa pine an Douglas-fir also increase the risk of individual tree "to out" and subsequent crowning and spotting.

Role Of Fire

The natural role of fire in Fire Group Two habitat ty is threefold (Davis and others 1980):

1. **To maintain grasslands**. Grassland areas capable supporting ponderosa pine and Douglas-fir could be kep treeless condition through frequent burning.
2. **To maintain open stands**. The open condition can perpetuated by periodic fires that reduce the number of seedlings, that remove dense understories of saplings o pole-sized trees, or that thin overstory trees.
3. **To encourage tree regeneration**. Fire exposes mineral soil, reduces seedling-damaging insect populatio reduces competing vegetation, and increases nutrient availability. Depending on the subsequent seed crop, weather, and continuity of the seedbed, regeneration m appear as dense stands, separated thickets, or scattered individuals. Periodic fires can create uneven-aged stand comprised of groups of trees that vary in age from grou to group. Severe fires may result in a predominantly ev aged stand if regeneration does occur.

Recent fire history studies on the Salmon National Forest provide some information on historical fire frequencies. Data from six small stands in the Colson Cree drainage (Barrett 1984) show mean fire intervals rangin from 10 to 18 years for both ponderosa pine and Dougla fir climax communities. Overall fire intervals range from 3 to 30 years. Other data from Salmon River ponderosa pine stands show presettlement mean fire intervals of 12 to 22 years (Arno and Wilson 1986). On the Boise National Forest, the mean fire interval for a stand belon ing to the PIPO/SYOR h.t. in the Boise Basin was 11 years for the period prior to 1900 (Steele and others 1986).

Before 1900, fire was a frequent event in ponderosa pi stands adjacent to western grasslands, occurring at intervals of from 5 to 25 years. Arno (1976) reported a range of 2 to 20 years and mean fire-free intervals of 6 to 12 years for fires occurring somewhere in small Group

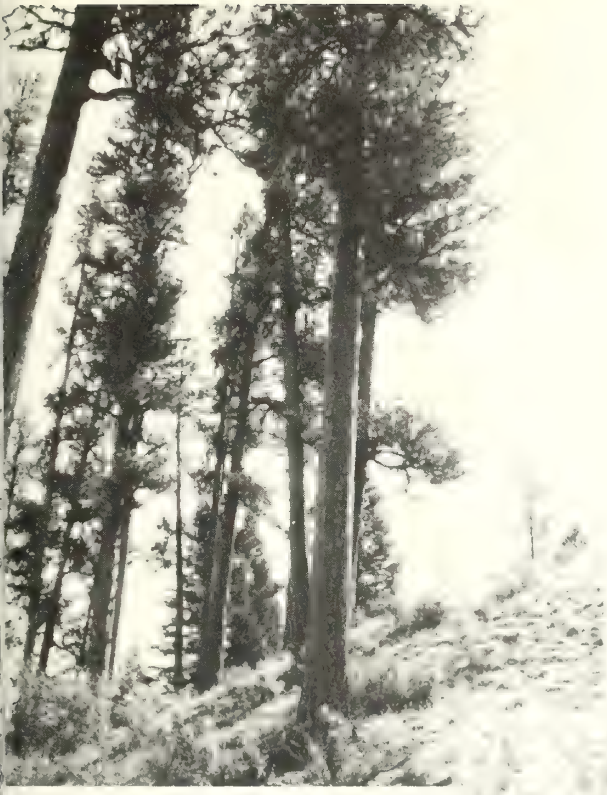


Figure 6—(A) PIPO/FEID h.t. on a warm, west-facing slope above the South Fork of the Salmon River, Salmon National Forest; (B) a PIPO/PUTR h.t. along the Middle Fork of the Boise River, Boise National Forest; (C) PIPO/FEID h.t. alongside the South Fork of the Payette River west of Lowman, ID, Boise National Forest. The widely spaced stumps indicate an open stand condition existed even before the last cutting.

Two ponderosa pine stands on the Bitterroot National Forest in western Montana. These figures should be considered conservative estimates of past mean fire intervals because many light surface fires can occur without scarring trees.

A fire interval of 50 years or more is suggested by Wright (1978) for the stands within the PIPO/PUTR h.t. He bases this hypothesis on observation and current knowledge of the susceptibility of bitterbrush to fire (Nord 1965; Weaver 1968; Wright 1978). Gruell (1986) suggests, however, that the fire interval was short and that many of the shrubs were not present in the densities we observe today. It has also been proposed that ponderosa pine communities with shrub undergrowth had longer fire intervals than those communities with grass undergrowth (Gruell and others 1982).

Successful fire control during the 20th century has undoubtedly affected some Group Two stands. In some areas, understory trees have created fuel ladders. Large, intense fires may result when fire control fails in these stands. Successful fire control also increases the area covered by Group Two stands by allowing ponderosa pine and Douglas-fir to invade formerly fire-maintained grasslands.

The relatively spotty or patchy distribution of dwarf mistletoe in ponderosa pine and Douglas-fir stands in central Idaho is due, in large part, to fire history. Severe fires often replaced infested stands with relatively mistletoe-free young stands. Partial burns resulting from less-than-severe fires often produced young trees that were rapidly infected by residual overstory trees that survived the fire (Alexander and Hawksworth 1975). According to Roth (1974a, 1974b), before fires were controlled in Oregon ponderosa pine stands, heat from repeated surface fires pruned back mistletoe-infected branches in the lower crowns, thus limiting the mistletoe plants to a sometimes inconspicuous presence high in the forest canopy (Alexander and Hawksworth 1975).

On Group Two sites, frequent light fires contribute little to soil erosion because few trees are killed and undergrowth and litter return quickly. An intense fire may accelerate erosion on the fragile batholith soils, but usually not as much as the mechanical disturbances often associated with modern fire suppression techniques.

Forest Succession

A generalized concept of forest succession in Fire Group Two and how fire affects this succession is shown in figure 7 (subsequent numbers in this section refer to fig. 7).

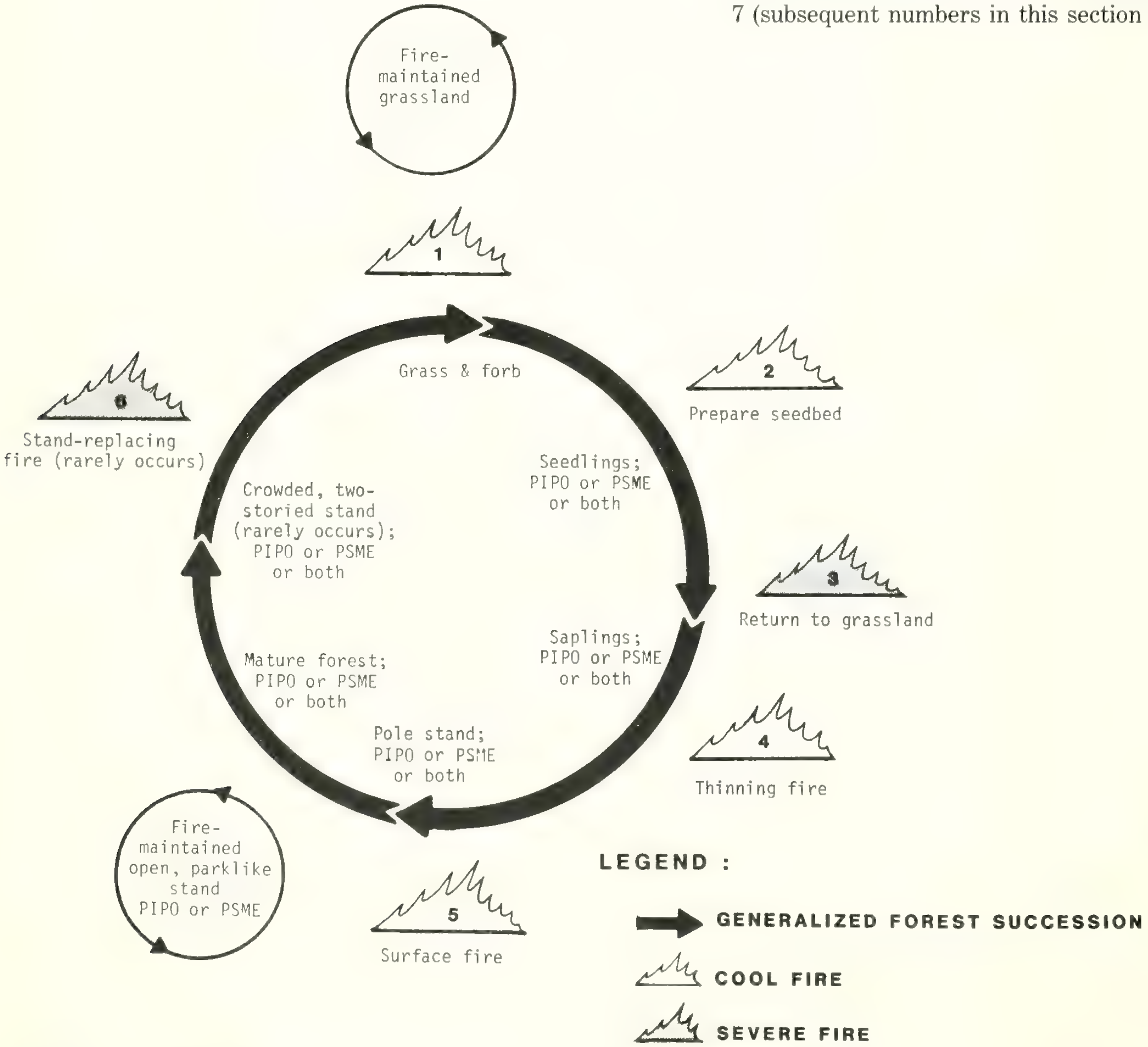

Fire-maintained grassland
1
Grass & forb
2
Prepare seedbed
6
Stand-replacing fire (rarely occurs)
Seedlings; PIPO or PSME or both
Crowded, two-storied stand (rarely occurs); PIPO or PSME or both
3
Return to grassland
Saplings; PIPO or PSME or both
Mature forest; PIPO or PSME or both
Pole stand; PIPO or PSME or both
4
Thinning fire
Fire-maintained open, parklike stand PIPO or PSME
5
Surface fire
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 7—Generalized forest succession in Fire Group Two: warm, dry ponderosa pine habitat types.

Frequent fires could maintain a grassland community by killing tree seedlings (No. 1). Grasses dominate the undergrowth, but other herbs and small shrubs may be present. Depending on habitat type (see appendix B), ponderosa pine or Douglas-fir seedlings may become established gradually over a long fire-free period, resulting in an all-aged, all-sized stand; or as a single age class following a seedbed-preparing fire (No. 2). In the absence of additional fires, the seedlings develop into saplings. Fires during this period may have the effect of killing the young trees (No. 3) or thinning them (No. 4).

With sufficient time the remaining trees mature to pole-size trees. Subsequent light ground fires tend to produce an open stand of mature trees (No. 5). The open nature of the stand is a direct result of the fires and stocking limitations and deteriorates if the fires are suppressed. The stand may then (in theory) become overstocked and accumulate enough fuel to support a severe stand-destroying fire (No. 6).

Successional pathways based on the combined effects of fire, plant succession, and fire exclusion are hypothesized in figure 8.

Fire Management Considerations

Silviculture—Hazardous fuels resulting from timber cutting can be reduced by prescribed burning. Depending on the situation, broadcast burning, understory burning, piling and burning, and jackpot burning may be appropriate. Lopping and scattering, unless followed by burning, is generally not an acceptable treatment, especially in ponderosa pine stands. "Red slash" creates a very serious fire hazard, particularly in partially cut or thinned pine stands, because needle fall and slash compaction occur so slowly. Fire hazard in untreated slash persists at a relatively high level for 3 to 5 years following cutting. Even after compaction is complete the hazard level will remain higher than before cutting. Carlton and Pickford (1982) predict that burning will produce a reduction in the depth of a ponderosa pine slash fuelbed equivalent to a natural settling period of 8 years for burns conducted in the spring, and at least 20 years for fall burns.

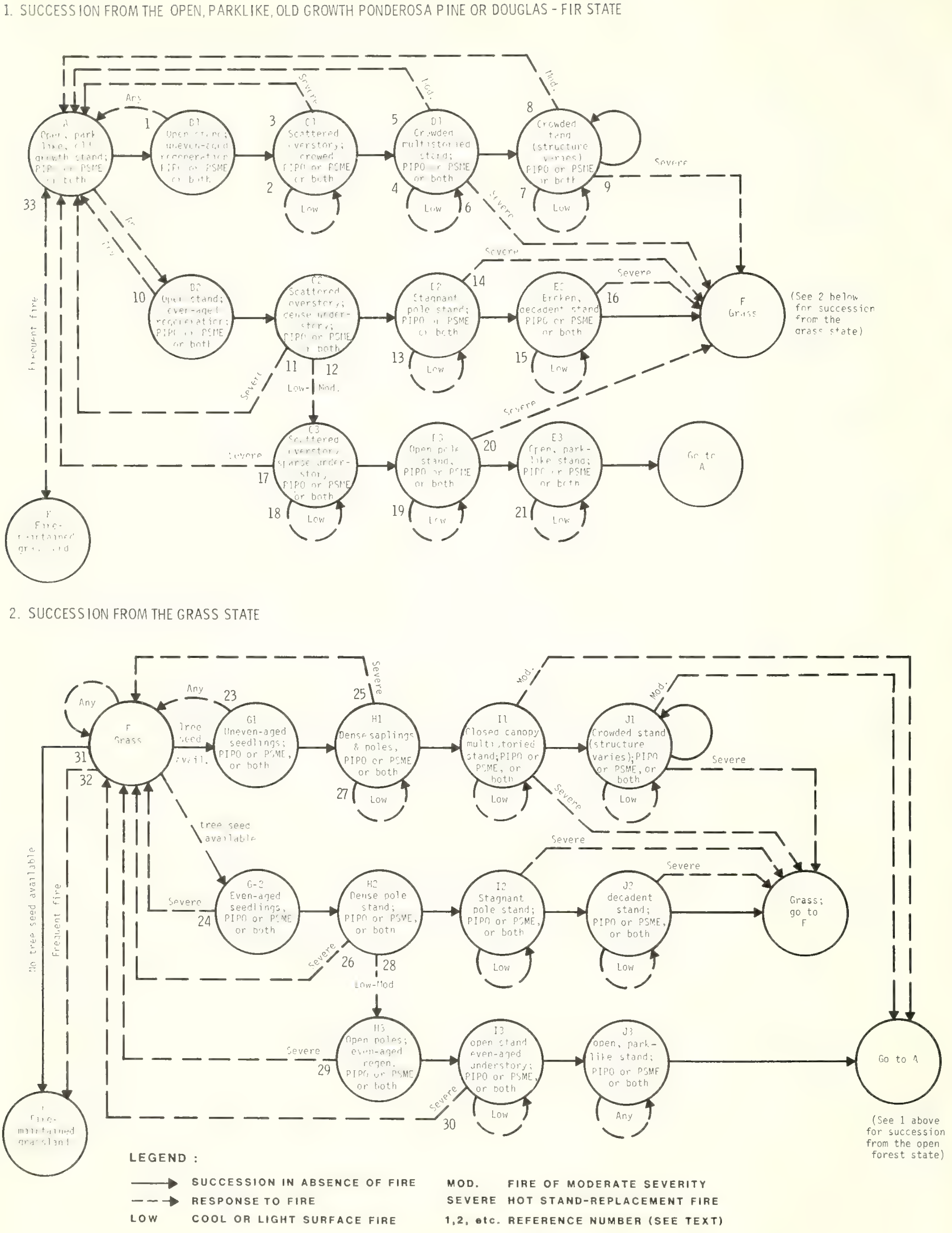
Fuel reduction burning generally results in removal of the duff layer over at least some of the burned area. The exposed mineral soil provides a favorable seedbed for ponderosa pine and Douglas-fir regeneration (Ryker and Losensky 1983).

Prescribed understory burning can be an effective tool for reducing natural fuel accumulations in undisturbed stands of ponderosa pine, thereby minimizing potential damage from subsequent wildfire. Such fires can be planned to accomplish multiple objectives, including hazard reduction, site preparation, and increased forage production for livestock and wildlife. Where especially heavy fuel loadings exist, a two-stage burning technique can be used to minimize unacceptable damage to overstory trees (Maupin 1981). First entry burns are usually low-intensity burns employing narrow strip headfires that produce short flame lengths and only partial fuel reduction. Desired fuel reduction is obtained by a subsequent fire conducted under more severe burning conditions.

Range and Wildlife Management—Many Fire Group Two sites support livestock grazing during the summer. Many sites are important winter range for elk, mule deer, and occasionally bighorn sheep. In spring, black bear feed heavily on the perennial grasses and forbs of many sites. Properly applied, fire can increase forage production and enhance the nutritional value of the forage produced. Where sparse fuels exist, grazing may have to be deferred for at least a year before burning in order to create adequate fuels to carry the fire.

For wildlife habitat management, prescribed fire can be used to increase undergrowth forage production, control vegetation composition, and increase habitat diversity. A prescribed fire frequency of 25 to 30 years is recommended to maintain or enhance presence of desirable shrubs (Gruell and others 1982). Low-intensity spring or fall fires can be used to stimulate sprouting and to improve seedling establishment in senescent stands of bitterbrush. More intense fires that expose mineral soil are recommended to rejuvenate decadent willow (USDA-FS 1982). General guidelines for the use of prescribed fire for wildlife habitat improvements in Intermountain Region ponderosa pine stands have been suggested by the Forest Service (1982).

Fire Control—Natural regeneration on Group Two sites is often sporadic and growth is generally slow. Fire control should be geared to protecting desirable advanced regeneration, especially in stands where stocking is limited.



1. SUCCESSION FROM THE OPEN, PARKLIKE, OLD GROWTH PONDEROSA PINE OR DOUGLAS - FIR STATE

A
Open, park like, old growth stand; PIPO or PSME or both
B1
Open stand; uneven-aged regeneration PIPO or PSME or both
C1
Scattered overstory; crowded PIPO or PSME or both
D1
Crowded multistoried stand; PIPO or PSME or both
Crowded stand (structure varies) PIPO or PSME or both
Any
Severe
Mod.
Mod.
Severe
Severe
Low
Low
Low
Low
1
2
3
4
5
6
7
8
9
33
Any
Any
10
B2
Open stand; even-aged regeneration; PIPO or PSME or both
C2
Scattered overstory; dense understory; PIPO or PSME or both
D2
Stagnant pole stand; PIPO or PSME or both
E2
Broken, decadent stand PIPO or PSME or both
F
Grass
(See 2 below for succession from the grass state)
Severe
Severe
14
16
13
15
Low
Low
11
12
Low-
Mod.
Severe
Frequent fire
C3
Scattered overstory, sparse understory, PIPO or PSME or both
D3
Open pole stand, PIPO or PSME or both
E3
Open, park-like stand; PIPO or PSME or both
Go to A
Severe
Severe
17
18
19
20
21
Low
Low
Low
F
Fire-maintained grassland

2. SUCCESSION FROM THE GRASS STATE

Any
Any
23
F
Grass
Tree seed avail.
G1
Uneven-aged seedlings; PIPO or PSME, or both
25
Severe
H1
Dense saplings & poles, PIPO or PSME or both
Mod.
I1
Closed canopy multistoried stand; PIPO or PSME, or both
Mod.
J1
Crowded stand (structure varies); PIPO or PSME, or both
Severe
Severe
27
Low
Low
Low
31
32
tree seed available
No tree seed available
Frequent fire
Severe
24
G-2
Even-aged seedlings, PIPO or PSME or both
H2
Dense pole stand; PIPO or PSME, or both
I2
Stagnant pole stand; PIPO or PSME, or both
J2
decadent stand; PIPO or PSME, or both
Grass; go to F
Severe
Severe
Severe
26
28
Low-Mod
Low
Low
H3
Open poles; even-aged regen. PIPO or PSME or both
I3
open stand even-aged understory; PIPO or PSME, or both
J3
open, park-like stand; PIPO or PSMF or both
Go to A
(See 1 above for succession from the open forest state)
Severe
29
Severe
30
Low
Any
Fire-maintained grassland
LEGEND :
——▶ SUCCESSION IN ABSENCE OF FIRE
– – ▶ RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 8—Hypothetical fire-related successional pathways for Fire Group Two habitat types: (1) hypothethical succession starting from an open, parklike, old growth ponderosa pine or Douglas-fir stand; and (2) hypothetical succession starting from the grass state.

FIRE GROUP THREE: WARM, MOIST PONDEROSA PINE HABITAT TYPES AND WARM, DRY DOUGLAS-FIR HABITAT TYPES USUALLY DOMINATED BY PONDEROSA PINE

ADP code	Habitat type-phase (Steele and others 1981)	Physiographic sections (Steele and others 1981)
170	*Pinus ponderosa/ Symphoricarpos albus* h.t. (PIPO/SYAL), ponderosa pine/common snowberry	Wallowa-Seven Devils, Salmon Uplands, and Southern Batholith
190	*Pinus ponderosa/Physocarpus malvaceus* h.t. (PIPO/PHMA), ponderosa pine/ninebark	Southern Batholith and Salmon Uplands
324	*Pseudotsuga menziesii/ Calamagrostis rubescens* h.t. - *Pinus ponderosa* phase (PSME/CARU-PIPO), Douglas-fir/pinegrass - ponderosa pine phase	Southern Batholith, Wallowa-Seven Devils, and Salmon Uplands
334	*Pseudotsuga menziesii/Carex geyeri* h.t. - *Pinus ponderosa* phase (PSME/CAGE-PIPO), Douglas-fir/elk sedge - ponderosa pine phase	Southern Batholith, Wallowa-Seven Devils, and Salmon Uplands
397	*Pseudotsuga menziesii/ Berberis repens* h.t. - *Symphoricarpos oreophilus* phase (PSME/BERE-SYOR), Douglas-fir/Oregon grape - mountain snowberry phase	Southern Batholith, Challis, and Open Northern Rockies
398	*Pseudotsuga menziesii/ Berberis repens* h.t. - *Carex geyeri* phase (PSME/BERE-CAGE), Douglas-fir/Oregon grape - elk sedge phase	Southern Batholith
344	*Pseudotsuga menziesii/ Spiraea betulifolia* h.t. - *Pinus ponderosa* phase (PSME/SPBE-PIPO), Douglas-fir/white spirea - ponderosa pine phase	Wallowa-Seven Devils, and Southern Batholith
315	*Pseudotsuga menziesii/ Symphoricarpos albus* h.t. - *Pinus ponderosa* phase (PSME/SYAL-PIPO), Douglas-fir/common snowberry-ponderosa pine phase	Wallowa-Seven Devils, Salmon Uplands, and Southern Batholith
262	*Pseudotsuga menziesii/ Physocarpus malvaceus* h.t. - *Calamagrostis rubescens* phase (PSME/PHMA-CARU), Douglas-fir/ninebark - pinegrass phase	Incidental in Salmon Uplands and Southern Batholith
264	*Pseudotsuga menziesii/ Physocarpus malvaceus* h.t. - *Pinus ponderosa* phase (PSME/PHMA-PIPO), Douglas-fir/ninebark - ponderosa pine phase	Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils

(con.)

Vegetation

Fire Group Three includes those warm, dry Douglas-fir habitat types where ponderosa occurs as a major seral or climax associate and two relatively moist ponderosa pine habitat types found in central Idaho. The Douglas-fir habitat types in this group may support fire-maintained ponderosa pine stands that develop a Douglas-fir understory in the absence of fire or other disturbance (Davis and others 1980). The vegetation within ponderosa pine habitat types included here (PIPO/SYAL, and PIPO/ PHMA h.t.'s) regenerates more readily than those in Fire Group Two, increasing the opportunity for the kind of fuel ladder development characteristic of stands belonging to Douglas-fir habitat types included in this group. Examples of Fire Group Three stands are shown in figure 9.

The habitat types within Fire Group Three occur predominantly at low to middle elevations within the Wallowa-Seven Devils, Salmon Uplands, and Southern Batholith physiographic sections of central Idaho. East and south of these sections, conditions are drier. The lower tree line occurs at higher elevations and includes little or no ponderosa pine (Steele and others 1981); thus these situations fall into other Fire Groups.

Many stands have a shrub-dominated undergrowth that includes common snowberry, white spirea, rose, chokecherry, ninebark, antelope bitterbrush, Oregon grape, serviceberry, willow, and mountain snowberry. Recently burned stands may have snowbrush ceanothus as a dominant species. Elk sedge and pinegrass dominate undergrowth in some stands. Other common herbs include oniongrass, arrowleaf balsamroot, sticky geranium, and silvery lupine (Steele and others 1981).

Forest Fuels

Fuel loads are heavier on the average than those found in Fire Group Two ponderosa pine stands. The average downed dead fuel load for comparable stands sampled in Montana was about 10 tons/acre (2.24 kg/m^2) with a range of from 2 to 30 tons/acre (0.45 to 6.73 kg/m^2) (Fischer 1981a).

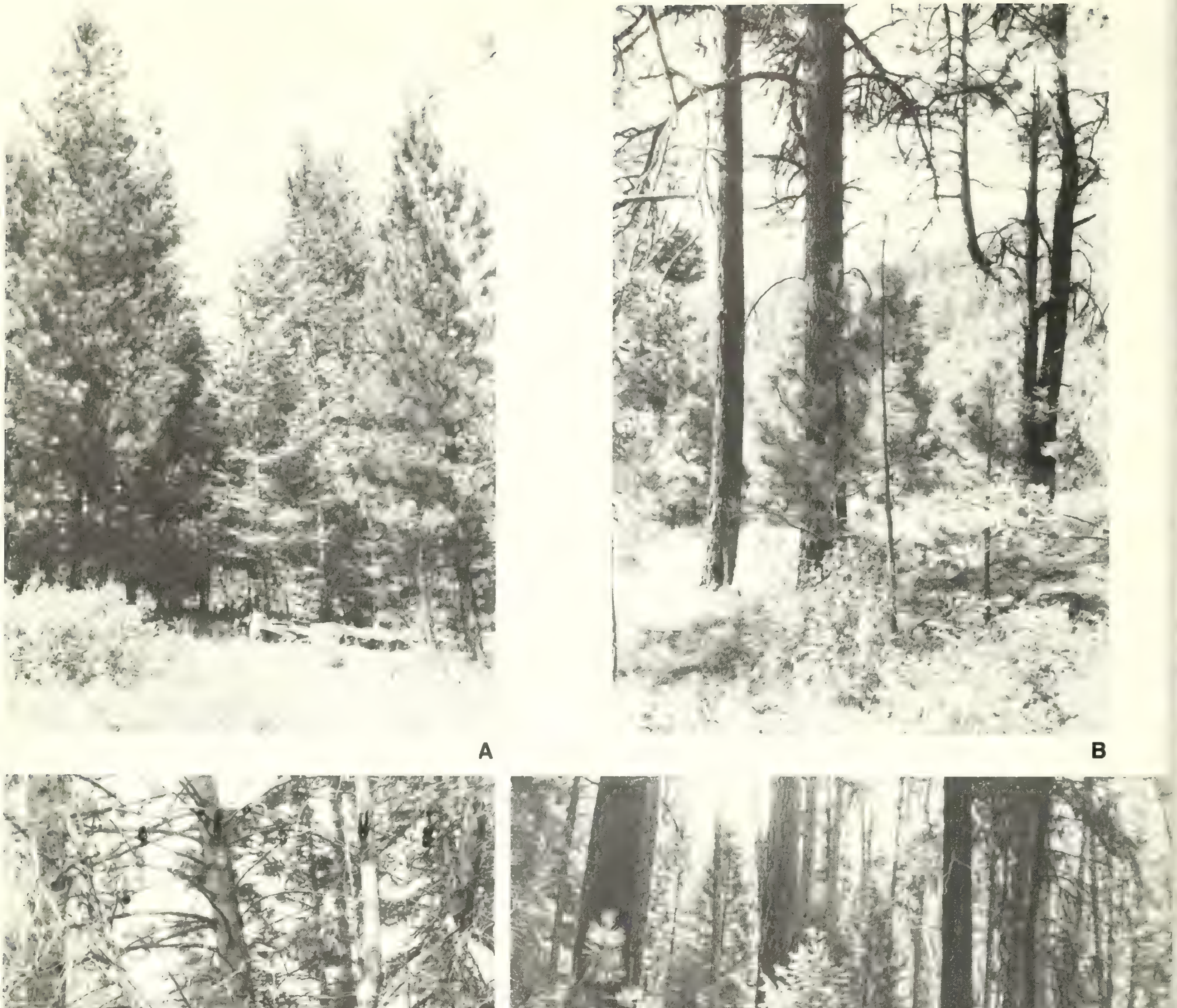


Figure 9—(A) A PSME/CARU-PIPO h.t. near Lick Creek, Payette National Forest. Ponderosa pine dominates the overstory, Douglas-fir dominates the understory. (B) A PIPO/SYAL h.t. on a southwest-facing ridge near Banks, ID, Boise National Forest. (C) A PSME/CARU-PIPO h.t. (D) A PSME/CARU-PIPO h.t. Both stands C and D have a mixed overstory of ponderosa pine and Douglas-fir and represent a later stage of succession than stand A. Stands C and D are located along the South Fork of the Salmon River, Payette National Forest.

Fuel conditions and associated fire hazard are usually determined by stand development which in turn is often governed by fire history. As a very general rule, fuel loads tend to increase with stand age as a result of accumulated downfall from insect and disease damage, blowdown, and natural thinning. Stands of the same age may, however, have widely different fuel loads. This is especially true in dense, young stands where heavy mortality from natural thinning or dwarf mistletoe infection (see Fire Group Two) can cause rapid fuel accumulation.

Live fuels can be a significant factor. Dense thickets of Douglas-fir regeneration may become established during fire-free periods. Overstory trees become susceptible to stand-destroying crown fires when such situations are allowed to develop. The presence of witches'-brooms also indicates a high potential for torch-out, crowning, and spotting.

Role of Fire

Fire's role in presettlement forest stands appears to have been important in establishing and maintaining open, old-growth stands. Relatively frequent fires:

1. Prepared seedbeds favorable to both ponderosa pine and Douglas-fir regeneration,
2. Controlled stocking levels in young stands, favoring sapling ponderosa pine over Douglas-fir,
3. Thinned suppressed pole-sized stands, again favoring ponderosa pine in mixed stands,
4. Maintained a ponderosa pine "fire climax" on Douglas-fir habitat types by killing the Douglas-fir understory,
5. Maintained open, parklike stands of ponderosa pine or Douglas-fir or open mixed stands of both species,
6. Prevented the development of "fuel ladders" of saplings or small poles that could carry fire into the crowns of the mature stand,
7. Pruned back mistletoe-infected branches in the lower crowns, thus limiting the mistletoe plants to a sometimes nconspicuous presence high in the forest canopy (Roth 1974a, 1974b), and
8. Regenerated browse and forage species.

Some of the most valuable ponderosa pine stands in central Idaho are growing on Douglas-fir sites because of reoccurring surface fires (Davis 1952). In the absence of fire, relatively dense, stagnant, multistoried Douglas-fir stands can develop. Not only are such stands susceptible to crown fires, but they are also often more susceptible to insect and disease problems.

Recent fire history investigations in the Colson Creek area, Salmon National Forest, suggest a mean fire interval of between 13 and 16 years for four small stands within the PSME/SYAL and PSME/PHMA h.t.'s (Barrett 1984). Fire intervals ranged from 3 to 30 years based on the method of Arno and Peterson (1983). Mean fire intervals ranging from 10 to 22 years have been determined for stands within the Boise Basin, Boise National Forest (Steele and others 1986). When these stands are arranged on a dry-to-moist gradient, the mean fire interval progressively increases: 9.8 years for a stand within the PSME/CAGE h.t., 10.3 years for a stand within the PSME/SPBE h.t., 12.8 years for a dry site PSME/PHMA stand, 15.9 years for a typical site PSME/PHMA stand, and 21.7 years for a moist site PSME/PHMA stand. All of the above stands occupy mid- to upper-slope positions. One stand belonging to the PSME/SPBE h.t. contradicted the dry-to-moist gradient, with a mean fire interval of 18.1 years. This stand was situated directly above a stream bottom; thus it is presumably less vulnerable to a spreading fire than the other stands. Remember, these short fire intervals represent historical fires; they very likely do not represent current fire history.

Light surface fires that temporarily remove regeneration and undergrowth should not be expected to cause serious erosion problems. Severe fires, on the other hand, can cause serious erosion and mass movement problems on the granitic soils common in this Fire Group (Gray and Megahan 1981). Severe stand-destroying fires have the effect of reducing evapotranspiration, which may increase the depth of the saturated zone relative to the soil depth, which in turn increases the landslide hazard (Megahan 1983).

LIBRARY

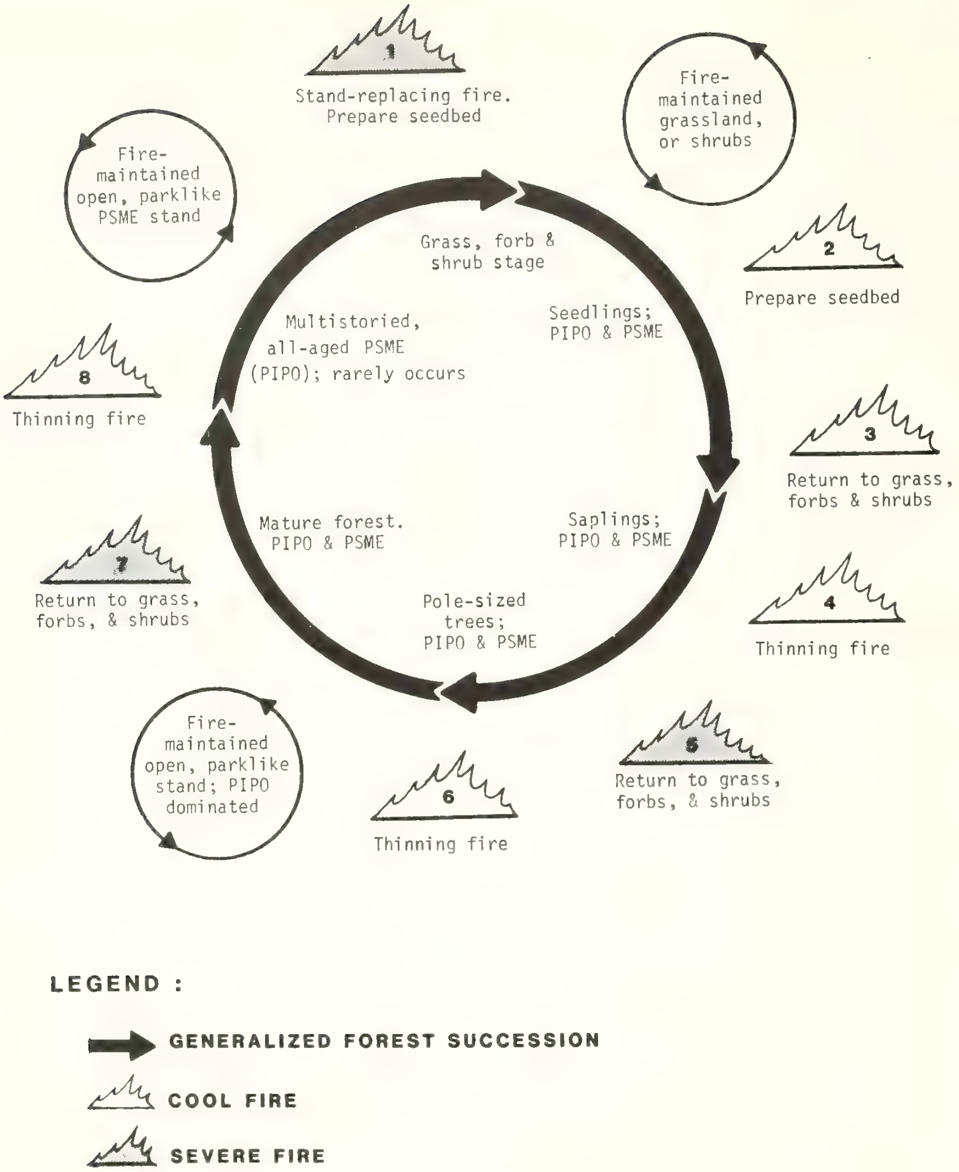
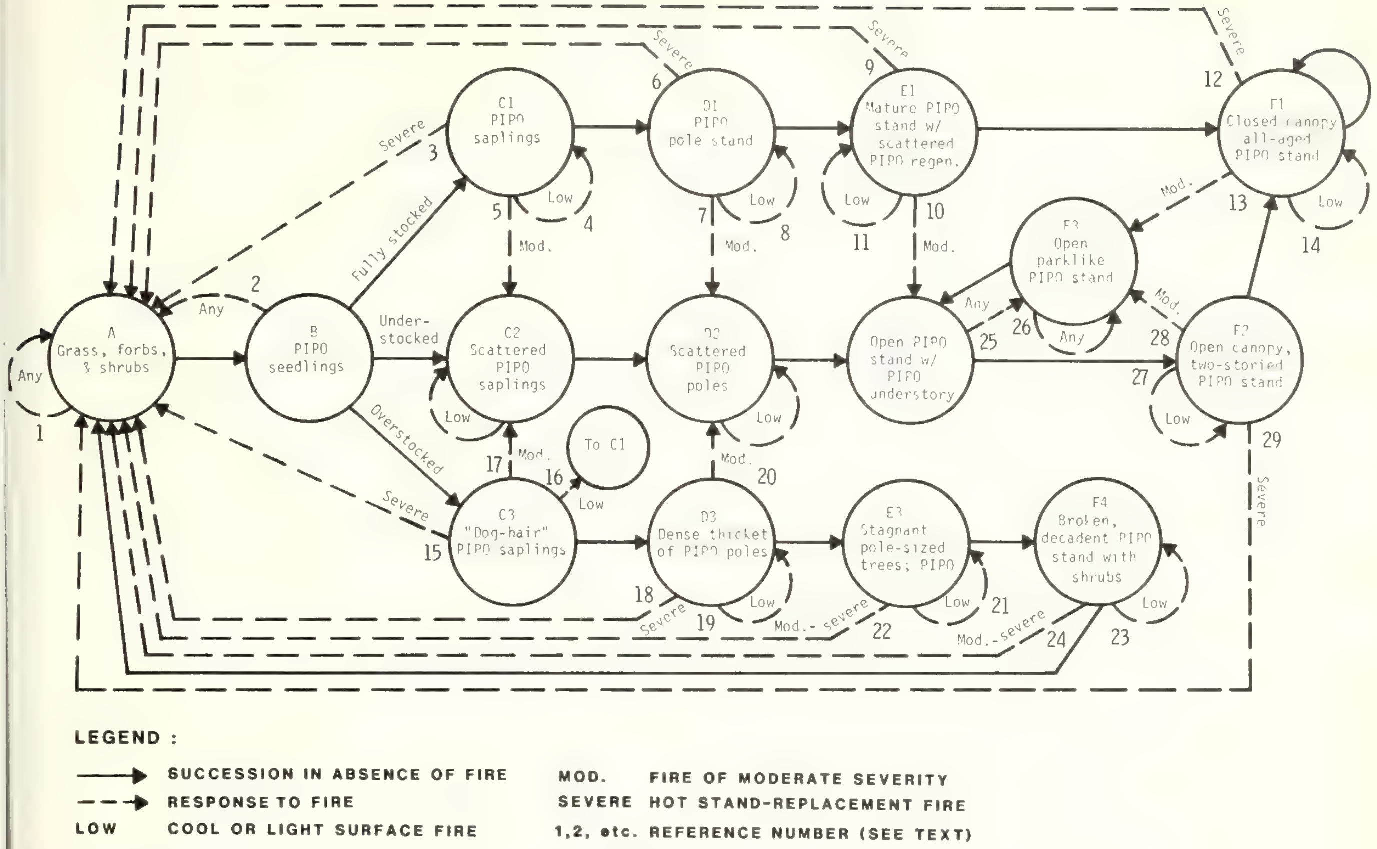

1
Stand-replacing fire.
Prepare seedbed
Fire-maintained grassland, or shrubs
Fire-maintained open, parklike PSME stand
Grass, forb & shrub stage
2
Prepare seedbed
Multistoried, all-aged PSME (PIPO); rarely occurs
Seedlings; PIPO & PSME
8
Thinning fire
3
Return to grass, forbs & shrubs
Mature forest. PIPO & PSME
Saplings; PIPO & PSME
7
Return to grass, forbs, & shrubs
Pole-sized trees; PIPO & PSME
4
Thinning fire
Fire-maintained open, parklike stand; PIPO dominated
5
Return to grass, forbs, & shrubs
6
Thinning fire
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 10—Generalized forest succession in Fire Group Three: warm, moist ponderosa pine habitat types and warm, dry Douglas-fir habitat types usually dominated by ponderosa pine.

Forest Succession

The theoretical Fire Group Three climax forest is an all-aged ponderosa pine or Douglas-fir stand. Old-growth stands tend to remain fairly open; but if dense understories develop, severe stand-replacing fire can occur, as shown in figure 10, No. 1 (subsequent numbers in this section refer to fig. 10). Grass, forbs, or shrubs along with conifer seedlings will become established on the site. Very frequent fires (No. 2) maintain a grass or herb and shrub community on the site. Given an adequate seed source and site preparation, seedlings usually become established and eventually dominate the site. Douglas-fir seedlings require some shade for successful establishment on most Group Three sites. Any fire during the seedling stage would return the site to the herbs and shrubs (No. 3). The effect of a fire in the sapling stage depends on stand composition and density. A relatively open stand of sapling ponderosa pine would be thinned by fire (No. 4). If Douglas-fir is present, the thinning will favor the pine. A cool surface fire would also thin a dense "dog hair" thicket of pine or pine and fir, again to the advantage of the pine. A moderately severe fire, however, would kill the entire thicket (No. 5). Pole stands that develop may be quite open, fully stocked, or overstocked. They may consist of ponderosa pine, a mixture of ponderosa pine and Douglas-fir, or perhaps only Douglas-fir. A light-to-moderate fire will thin the stand, removing undergrowth and susceptible Douglas-fir or ponderosa pine stems. Subsequent fires could maintain an open, ponderosa pine-dominated stand. Severe fires in young stands (No. 7) return the site to herbs and shrubs. Low-to-moderate fires remove existing regeneration and keep mature stands open (No. 8). Such fires also prepare the site for new regeneration. In the absence of fire, a multistoried all-aged stand of pine or fir will develop.


A
Grass, forbs, & shrubs
Any
1
B
PIPO seedlings
Any
2
Severe
3
Fully stocked
Under-stocked
Overstocked
C1
PIPO saplings
Low
4
5
Mod.
C2
Scattered PIPO saplings
Low
C3
"Dog-hair" PIPO saplings
15
Severe
17
Mod.
16
Low
To C1
D1
PIPO pole stand
6
Severe
7
Mod.
Low
8
D2
Scattered PIPO poles
Low
D3
Dense thicket of PIPO poles
Mod.
20
18
Severe
19
Low
E1
Mature PIPO stand w/ scattered PIPO regen.
9
Severe
Low
11
10
Mod.
Open PIPO stand w/ PIPO understory
E3
Stagnant pole-sized trees; PIPO
Mod.-severe
22
Low
21
F1
Closed canopy all-aged PIPO stand
12
Severe
Low
14
Mod.
13
F3
Open parklike PIPO stand
Any
25
26
Any
Mod.
28
F2
Open canopy, two-storied PIPO stand
27
Low
29
Severe
F4
Broken, decadent PIPO stand with shrubs
Mod.-severe
24
Low
23
LEGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

igure 11—Hypothetical fire-related successional pathways for Fire Group Three ponderosa ine habitat types.

Hypothetical fire-related successional pathways for Fire Group Three are presented in figures 11 and 12. Figure 11 refers to ponderosa pine habitat types. Figure 12 refers to the Douglas-fir habitat types. Many of the successional stages and pathways hypothesized for Fire Group Two ponderosa pine stands (fig. 4) also apply to ponderosa pine stands in Fire Group Three. The major difference is that Group Three stands tend more toward the dense all-age and multistory condition than to the open, parklike condition shown for Group Two.

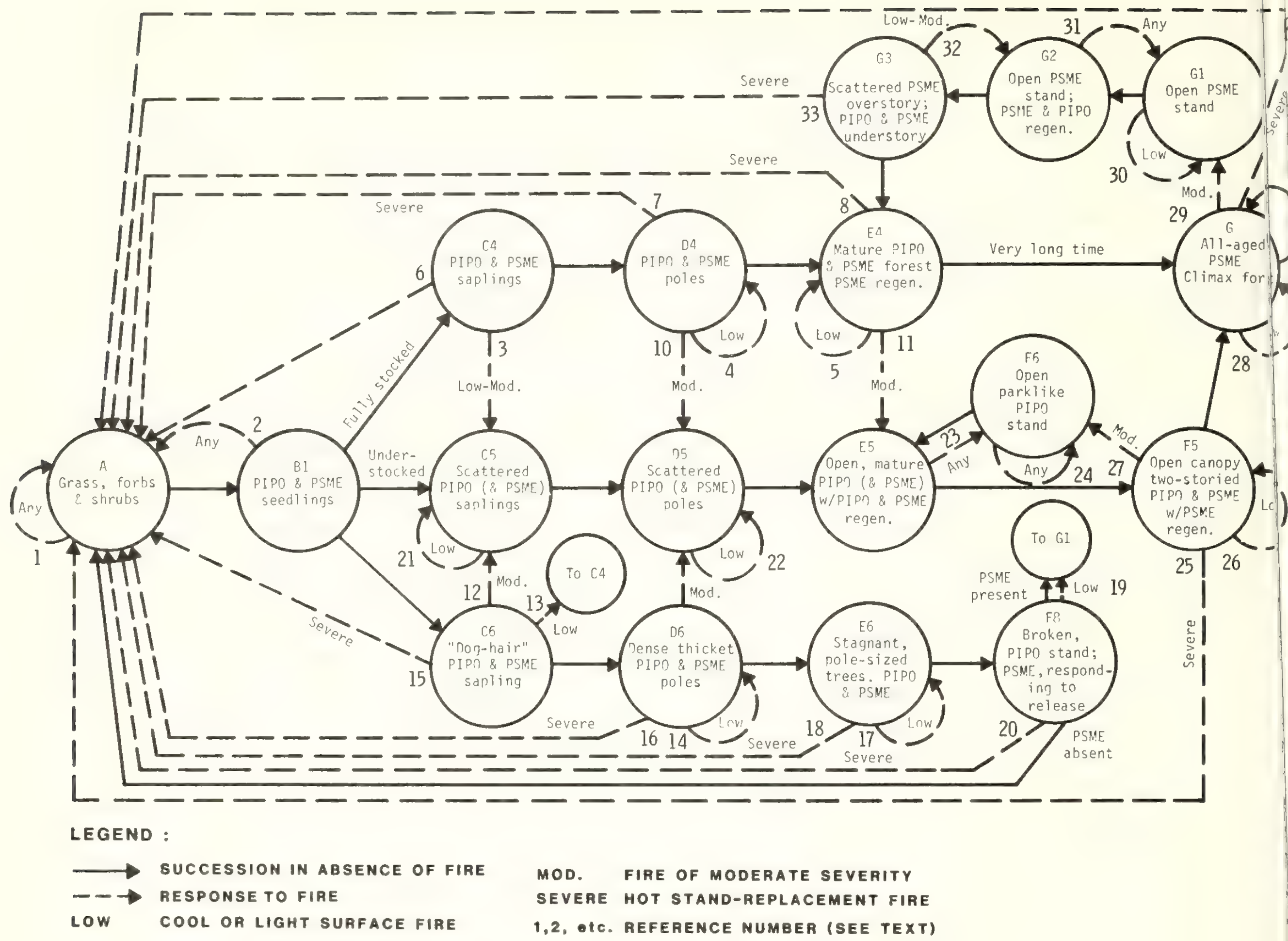

A
Grass, forbs & shrubs
Any
1
B1
PIPO & PSME seedlings
Any
2
Fully stocked
Under-stocked
C4
PIPO & PSME saplings
C5
Scattered PIPO (& PSME) saplings
C6
"Dog-hair" PIPO & PSME sapling
D4
PIPO & PSME poles
D5
Scattered PIPO (& PSME) poles
D6
Dense thicket PIPO & PSME poles
E4
Mature PIPO & PSME forest PSME regen.
E5
Open, mature PIPO (& PSME) w/PIPO & PSME regen.
E6
Stagnant, pole-sized trees. PIPO & PSME
F5
Open canopy two-storied PIPO & PSME w/PSME regen.
F6
Open parklike PIPO stand
F8
Broken, PIPO stand; PSME, responding to release
G
All-aged PSME Climax for
G1
Open PSME stand
G2
Open PSME stand; PSME & PIPO regen.
G3
Scattered PSME overstory; PIPO & PSME understory
To C4
To G1
Very long time
Low-Mod.
Mod.
Low
Severe
Any
PSME present
PSME absent
3
4
5
6
7
8
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
LEGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 12—Hypothetical fire-related successional pathways for Fire Group Three Douglas-fir habitat types.

Fire Management Considerations

Wildfire Hazard Reduction—In the absence of fire, hazardous fuel situations can develop in Group Three stands. The combination of dense Douglas-fir or ponderosa pine understories, accumulated deadfall, decadent shrubs, and other types of accumulated debris and litter can produce fires severe enough to scorch the crowns and kill the cambium of overstory trees. Brown and others (1985) have determined relationships for predicting consumption of forest floor duff and downed, dead, woody fuel to assist managers in planning prescribed fires to safely reduce this hazard. Prescribed fire can also be used to reduce the hazard associated with logging slash resulting from clearcuts and partial cuts. Most fire prescriptions can be written so as to accomplish silvicultural, range, and wildlife objectives as well as hazard reduction.

Silviculture—Where timber management is the objective, fire can be used to dispose of slash and eliminate mistletoe-infected residual trees on logged over areas, prepare seedbeds, reduce herbaceous competition before planting, control species composition, and reduce the probability of stand-destroying wildfires. Where ponderosa pine is a favored timber species, fire can be used to remove unwanted Douglas-fir regeneration once the pine attains a diameter of 5 inches (13 cm) or more. Wright (1978) recommends that there be an adequate number of trees 10 to 12 feet (3 to 4 m) tall before regular prescribed burning begins, although low-intensity surface fires will often leave pine 6 to 8 feet (2 to 2.5 cm) tall unharmed. Larger Douglas-fir trees will also survive most low-severity surface fires; so there need be little concern about completely eliminating fir from the stand. Where bole or root decay is common on overstory Douglas-fir, increased mortality should, however, be expected.

The practice of prescribed underburning in ponderosa pine-Douglas-fir stands may also reduce the susceptibility of such stands to damage by the western spruce budworm (*Choristoreura fumiferama*) and the tussock moth (*Hemerocampa pseudotsugata*) (Fellin 1980).

The use of fire on some sites, especially those within the PSME/CARU-PIPO h.t., may result in heavy coverages of pinegrass, especially following low- to moderate-severity fires. The resulting dense sod may impede tree seedling establishment, especially in the absence of bulldozer scarification. Weaver (1957) reports that successful regeneration of ponderosa pine on grassy sites in eastern Washington occurred on spots where slash piles were burned. Ponderosa pine seedlings planted on burned spots had increased survival and height growth after 5 years on sites within the PSME/PHMA h.t. on the Payette National Forest (Hall 1971).

On some sites, burning results in a lush vegetation of snowbrush ceanothus originating from seed stored in the forest floor. This situation, while favorable to wildlife, may impede seedling establishment and early development. Preharvest underburns coupled with a shelterwood cut that leaves an overstory in control of the site may discourage development of snowbrush (Martin 1982).

Range and Wildlife Habitat Management—Deer and elk winter and spring ranges can be rejuvenated with properly applied prescribed fire. Such fires can reduce establishment of Douglas-fir, remove accumulated dead plant materials, recycle nutrients, regenerate old shrubs, and increase distribution and production of nutrient-rich grasses, forbs, and legumes. On some sites burning will result in a lush vegetation of snowbrush ceanothus, a favored browse species. Willms and others (1980) found that deer and cattle preferred forage from burned Douglas-fir/bluebunch wheatgrass communities over unburned control areas. Refer to Fire Group Two fire management considerations for general guidelines for the use of prescribed fire for wildlife habitat improvement in ponderosa pine forests.

Recreation and Esthetics—Prescribed fire can be used to reduce fire hazard in areas immediately adjoining campgrounds. Such treatment not only reduces fire hazard, but also improves viewing and foot travel from the campground to the surrounding forest.

FIRE GROUP FOUR: COOL, DRY DOUGLAS-FIR HABITAT TYPES

ADP code	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
372	*Pseudotsuga menziesii/ Arnica cordifolia* h.t. - *Astragalus miser* phase (PSME/ARCO-ASMI), Douglas-fir/heartleaf arnica - weedy milkvetch phase	Challis and Open Northern Rockies
371	*Pseudotsuga menziesii/ Arnica cordifolia* h.t. - *Arnica cordifolia* phase (PSME/ARCO-ARCO), Douglas-fir/heartleaf arnica - heartleaf arnica phase	Challis and Open Northern Rockies
360	*Pseudotsuga menziesii/ Juniperus communis* h.t. - (PSME/JUCO), Douglas-fir/ common juniper	Challis and Open Northern Rockies
332	*Pseudotsuga menziesii/Carex geyeri* h.t. - *Symphoricarpos oreophilus* phase (PSME/CAGE-SYOR), Douglas-fir/elk sedge - mountain snowberry phase	Southern Batholith, Salmon Uplands, Challis, and Open Northern Rockies
331	*Pseudotsuga menziesii/Carex geyeri* h.t. - *Carex geyeri* phase (PSME/CAGE-CAGE), Douglas-fir/elk sedge - elk sedge phase	Challis, Southern Batholith, and Open Northern Rockies
385	*Pseudotsuga menziesii/ Cercocarpus ledifolius* h.t. (PSME/CELE), Douglas-fir/curlleaf mountain-mahogany	Challis, Open Northern Rockies, Southern Batholith, and Salmon Uplands

ADP code	Habitat type-phase (Steele and others 1981)	Physiographic sections (Steele and others 1981)
325	*Pseudotsuga menziesii/ Calamagrostis rubescens* h.t. - *Festuca idahoensis* phase (PSME/CARU-FEID), Douglas-fir/pinegrass - Idaho fescue phase	Challis, Open Northern Rockies, Southern Batholith, and Salmon Uplands
323	*Pseudotsuga menziesii/ Calamagrostis rubescens* h.t. - *Calamagrostis rubescens* phase (PSME/ CARU-CARU), Douglas-fir/ pinegrass - pinegrass phase	Challis, Open Northern Rockies, Southern Batholith, and Salmon Uplands
343	*Pseudotsuga menziesii/ Spiraea betulifolia* h.t. - *Calamagrostis rubescens* phase (PSME/SPBE-CARU), Douglas-fir/white spirea - pinegrass phase	Challis, Salmon Uplands, and Southern Batholith
344	*Pseudotsuga menziesii/ Spiraea betulifolia* h.t. - *Spiraea betulifolia* phase (PSME/SPBE-SPBE), Douglas-fir/white spirea - white spirea phase	Southern Batholith, Challis, Salmon Uplands, and Open Northern Rockies
310	*Pseudotsuga menziesii/ Symphoricarpos albus* h.t. - *Symphoricarpos albus* phase (PSME/SYAL-SYAL), Douglas-fir/common snowberry - common snowberry phase	Open Northern Rockies, Salmon Uplands, and Southern Batholith
392	*Pseudotsuga menziesii/Acer glabrum* h.t. - *Symphoricarpos oreophilus* phase (PSME/ACGL-SYOR), Douglas-fir/mountain maple - mountain snowberry phase	Challis and Open Northern Rockies
493	*Picea engelmannii/Hypnum revolutum* h.t. (PIEN/ HYRE), spruce/hypnum	Open Northern Rockies

Vegetation

Douglas-fir is the indicated climax within all habitat types except the PIEN/HYRE h.t. It generally dominates later successional stages as well. Habitat types in this group are generally too cold for ponderosa pine, although it may be a coclimax species at the warmest and driest extreme of the PSME/CELE h.t. With the exceptions of some sites within the PSME/CARU-CARU and PSME SPBE-CARU h.t.'s lodgepole pine is not a major seral species. Examples of Fire Group Four stands are shown figure 13.

Forests in this group tend to be open, and tree regeneration is often difficult and sporadic. Undergrowth may be sparse but strongly competitive with tree seedlings following disturbance. Elk sedge and pinegrass dominate the undergrowth on some sites. Other grasses and forbs include bluebunch wheatgrass, Idaho fescue, pussytoes ballhead sandwort, heartleaf arnica, weedy milkvetch, arrowleaf balsamroot, sticky geranium, and silvery lupine Common shrubs include mountain snowberry, chokecherry currant, big sagebrush, mountain mahogany, russet buffaloberry, willow, Oregon grape, woods rose, white spirea, common snowberry, mountain maple, and snowbrush ceanothus.

Most of the habitat types in this group have their main distribution in the Open Northern Rockies and Challis physiographic sections. These sections lie on the east side of major mountain systems and generally do not receive full benefit of winter storms bringing moisture from the Pacific Ocean. They do, however, receive some summer rain from storms originating from the Gulf of Mexico and California coast (Steele and others 1981). This basically dry climate with summer rain has several consequences:

1. Tree growth is slow.
2. Tree seedlings establish readily with the aid of summer rain if seed is available.
3. Trees in overstocked stands do not respond well to release.
4. Lightning-caused fires are infrequent.

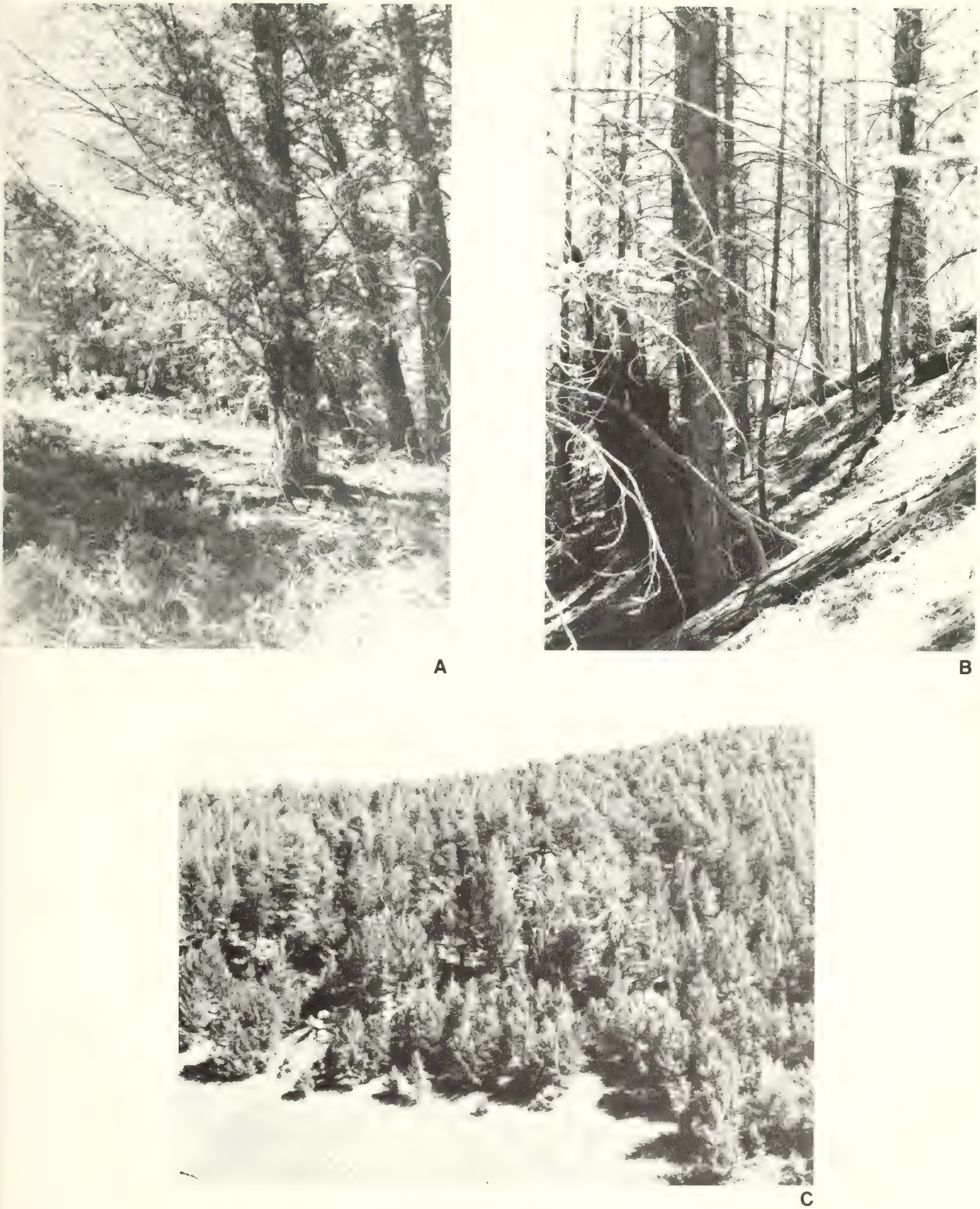


Figure 13—(A) A PSME/JUCO h.t. (B) A PSME/ARCO h.t. Both stands are in the Wildcat Creek drainage near Leadore, ID, Salmon National Forest. (C) A lower timberline forest on a north-facing slope in Railroad Canyon. Old limber pine show among the Douglas-fir, indicating an earlier stage of succession.

Forest Fuels

Downed, dead, woody fuels are relatively light. Similar sites in Montana averaged about 13 tons/acre (3 kg/m^2) (Brown and See 1981). Twigs and small branchwood less than 3 inches (7.62 cm) in diameter usually are the predominant woody fuels on the forest floor. Fine fuels are less abundant in this group than in Groups One, Two, and Three. Both undergrowth and regeneration are usually sparse. Individual Douglas-fir trees will, however, often have branches close to the ground; if sufficient ground fuels are available, torching can occur. The large, dense witches'-brooms caused by dwarf mistletoe in Douglas-fir are often broken from the trees during snowstorms. These accumulate around the bases of the trees and increase the likelihood of torching from surface fires (Weir 1916; Alexander and Hawksworth 1975). Also, large brooms on living or standing dead trees may promote crown fires and spot fires.

The combination of widely spaced, thick-barked trees and the characteristically depauperate undergrowth results in a very low fire hazard for most open stands of old-growth Douglas-fir.

Role Of Fire

The natural role of fire is poorly defined for this group. Severe stand-replacing fires seem likely for dense stands of the Open Northern Rockies and Challis physiographic sections, where relatively few lightning ignitions occur. In other areas relatively light fuel loads, sparse undergrowth, and generally open stands also suggest a relatively long fire interval. In southwestern Montana, Arno and Gruell (1983) estimated a mean fire-free interval of 41 years within the PSME/CARU-CARU h.t. Fire may have created and maintained open stand conditions by thinning pole stands and periodically removing understory seedlings. The probable role of fire in the distribution of dwarf mistletoe on Douglas-fir is as reported for Fire Group Two.

Severe stand-destroying fires may lead to accelerated erosion on some sites. Sites on granite substrates within the Southern Batholith and Salmon Uplands physiographic sections are the most susceptible to mass wasting following severe fires.

Forest Succession

The generalized forest succession discussed here and illustrated by figure 14 assumes that Douglas-fir is the dominant seral species on the site as well as the climax within all habitat types except the PIEN/HYRE h.t., where spruce is the theoretical climax. Sites where lodgepole pine is a dominant seral species (some sites within the PSME/CAGE-CAGE and PSME/SPBE-CARU h.t.'s) are represented in figure 18 (see Fire Group Five).

Frequent fire can maintain Fire Group Four sites as grasslands, as shown in figure 14, No. 1 (subsequent

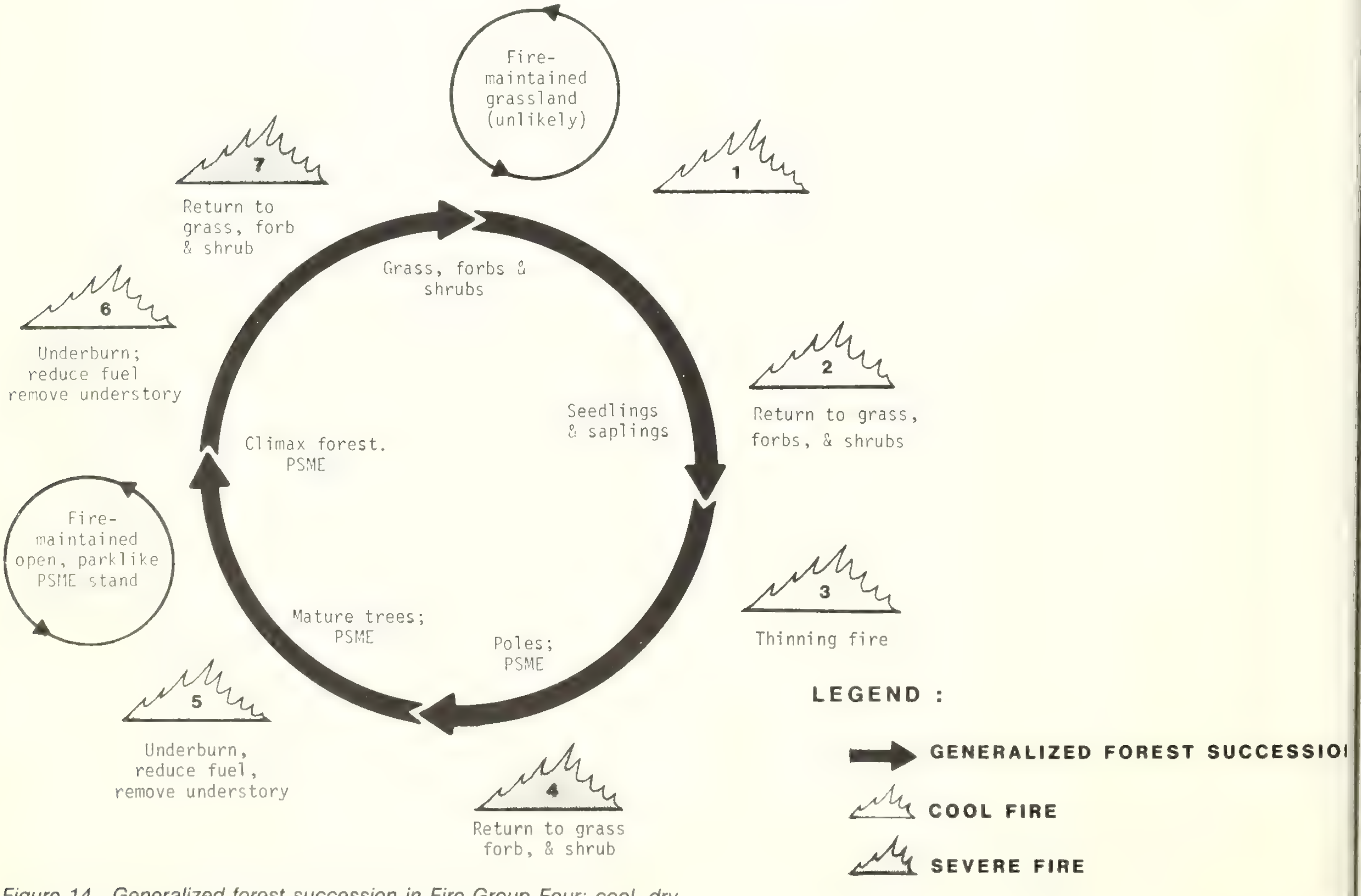
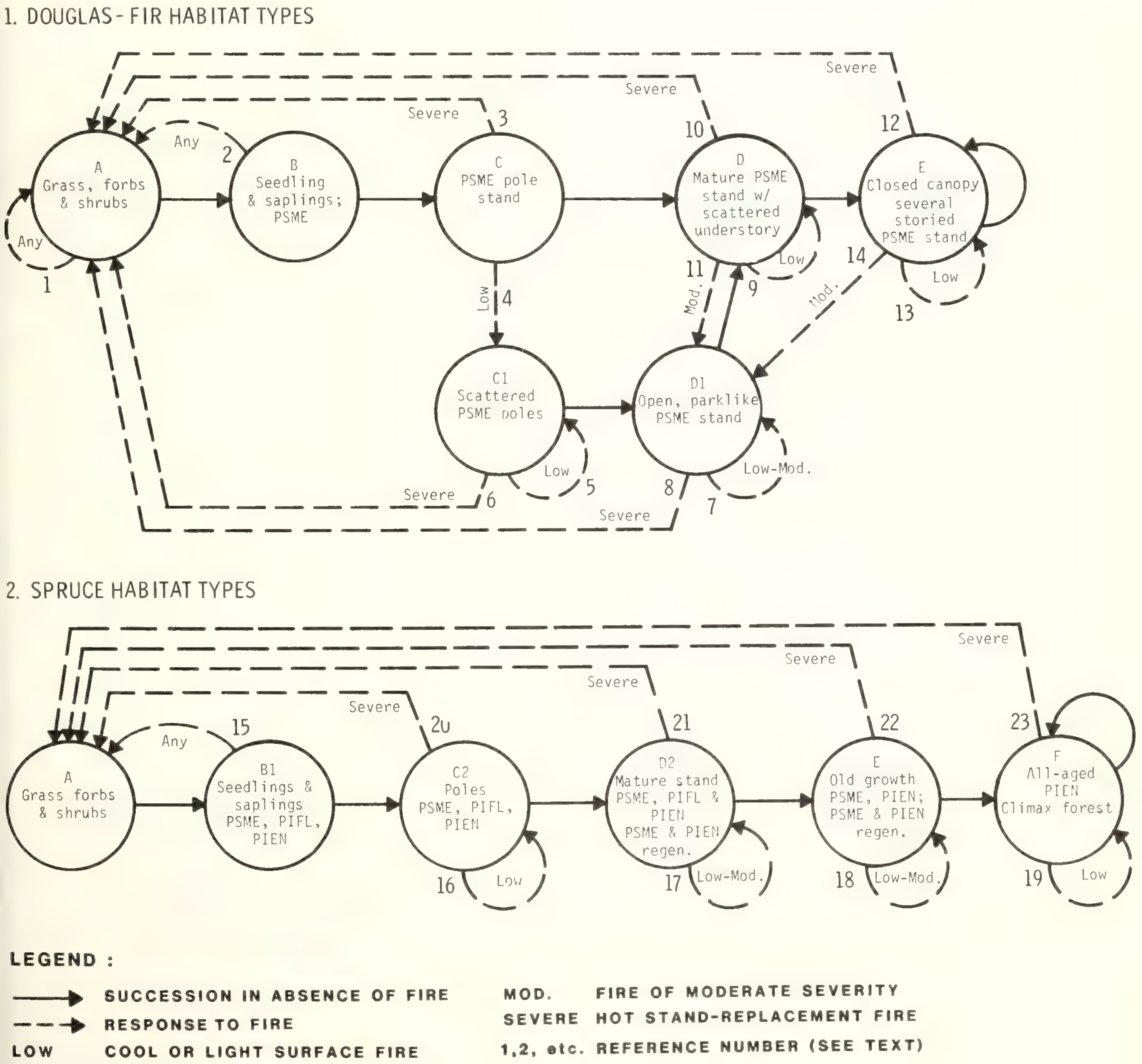

Fire-maintained grassland (unlikely)
7
Return to grass, forb & shrub
1
Grass, forbs & shrubs
6
Underburn; reduce fuel remove understory
2
Return to grass, forbs, & shrubs
Seedlings & saplings
Climax forest. PSME
Fire-maintained open, parklike PSME stand
3
Thinning fire
Mature trees; PSME
Poles; PSME
5
Underburn, reduce fuel, remove understory
4
Return to grass forb, & shrub
LEGEND :
GENERALIZED FOREST SUCCESSIO
COOL FIRE
SEVERE FIRE

Figure 14—Generalized forest succession in Fire Group Four: cool, dry Douglas-fir habitat types beyond the normal range of ponderosa pine.

numbers in this section refer to fig. 14). Seedling establishment is often slow and requires a combination of favorable seedbed, adequate moisture, and abundant seed. When favorable conditions for seedling establishment do occur, an even-aged stand usually develops. Any fire in either seedling or sapling stages returns the site to grass (No. 2).

A light surface fire thins a pole-sized stand by killing the more susceptible stems (No. 3). A pole stand (No. 4) is killed by a severe fire, and the site returns to the grassy stage. A less-than-severe fire in a mature stand (No. 5) acts as an underburn and thins and opens the stand. Subsequent light fires maintain the open condition leading to a parklike Douglas-fir or Douglas-fir and spruce stand. In the absence of fire a near-climax situation develops. The near climax is characterized by a Douglas-fir or Douglas-fir and spruce overstory, sparse undergrowth, and moderate amounts of dead fuel on the forest floor. A light fire in such a stand will remove undergrowth and reduce dead woody fuel (No. 6). A severe fire (No. 7) in a climax or near-climax stand will destroy the stand and revert the site to the grass/forb/shrub state.

Hypothetical successional pathways following fire and the absence of fire for most Group Four habitat sites are presented in figure 15. Figure 15 does not adequately represent those sites on which lodgepole pine is a major seral component (some sites within the PSME/CAGE-CAGE and PSME/PSME-CARU h.t.'s). Succession on those sites is better represented in figure 19 (see Fire Group Five).


1. DOUGLAS-FIR HABITAT TYPES

A
Grass, forbs & shrubs
B
Seedling & saplings; PSME
C
PSME pole stand
D
Mature PSME stand w/ scattered understory
E
Closed canopy several storied PSME stand
C1
Scattered PSME poles
D1
Open, parklike PSME stand
Any
1
Any
2
Severe
3
Low
4
Low
5
Severe
6
Low-Mod.
7
Severe
8
Low
9
Severe
10
Mod.
11
Severe
12
Low
13
Mod.
14

2. SPRUCE HABITAT TYPES

A
Grass forbs & shrubs
B1
Seedlings & saplings PSME, PIFL, PIEN
C2
Poles PSME, PIFL, PIEN
D2
Mature stand PSME, PIFL & PIEN PSME & PIEN regen.
E
Old growth PSME, PIEN; PSME & PIEN regen.
F
All-aged PIEN Climax forest
Any
15
Low
16
Low-Mod.
17
Low-Mod.
18
Low
19
Severe
2u
Severe
21
Severe
22
Severe
23

LEGEND :

——▶	**SUCCESSION IN ABSENCE OF FIRE**	**MOD.**	**FIRE OF MODERATE SEVERITY**
– – –▶	**RESPONSE TO FIRE**	**SEVERE**	**HOT STAND-REPLACEMENT FIRE**
LOW	**COOL OR LIGHT SURFACE FIRE**	**1,2, etc.**	**REFERENCE NUMBER (SEE TEXT)**

Figure 15—Hypothetical fire-related successional pathways for Fire Group Four habitat types.

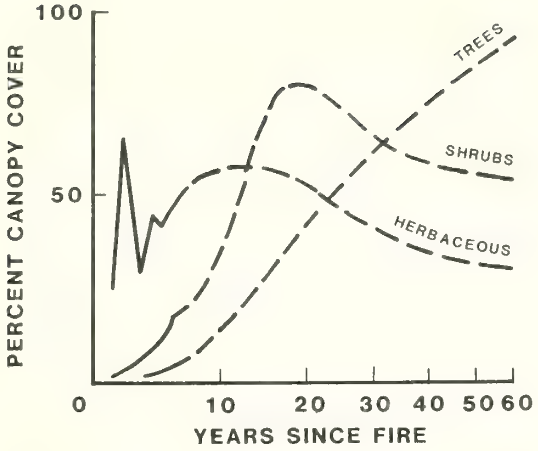


Figure 16—Theoretical development of Neal Canyon vegetal community (Lyon 1971).

Fire Management Considerations

Hazard Reduction and Site Preparation—Fire can be used following timber harvest to prepare seedbed (Ryker and Losensky 1983) and to reduce wildfire hazard from logging slash. Care must be taken to control fire intensity when burning in partially cut stands. The hazard reduction objective in such situations should be to remove fine fuels only. Attempts to burn larger sized slash could result in fire damage to the residual trees. Also, scattered large logs may provide the necessary protection needed for Douglas-fir seedling survival.

Where pinegrass is a component of the undergrowth, burning may lead to an increase in cover and density. This condition requires careful site preparation for successful regeneration of conifers (Steele and others 1981).

Wildlife Management—The occurrence of wildfire or the application of prescribed fire following logging can result in very favorable big game habitat on some sites, especially where snowbrush ceanothus seed is stored in the soil. The resulting seral stands of snowbrush, willow, aspen, mountain maple, serviceberry, and other preferred wildlife browse are very important to deer and elk. In some areas, the sites may be important for fawning and calving (Steele and others 1981).

A Prescribed Fire Case Study—A selectively logged stand of Douglas-fir in Neal Canyon on the Ketchum Ranger District, Sawtooth National Forest, was burned with prescribed fire on August 1, 1963. Major habitat types represented on the area are PSME/CARU (Fire Group Four) and PSME/ACGL (Fire Groups Four and Five). The basic objective of the fire was to destroy residual trees in a partially cut stand that was so heavily infested by dwarf mistletoe that the site was unproductive, and to regenerate a young healthy stand. The prefire stand contained mostly mistletoe-deformed saplings and poles. Lyon (1971) presents descriptions of the fire, the prefire forest community, and the first 7 years of postfir vegetal development. Effects on wildlife habitat are stressed.

The Neal Canyon prescribed fire was burned during daylight hours under conditions severe enough to produc crown fire in the overstory. All litter and herbaceous plants, all dead woody stems under 3 inches (7.6 cm) in diameter, and all live stems under 2 inches (5.1 cm) wer completely consumed.

After seven growing seasons, the early seral herbaceo community contained nearly twice as many species as th preburn community. Virtually all the perennial herbaceo species resprouted and many new species appeared. Pos fire canopy cover never dropped significantly below preburn levels (Lyon 1971).

The Douglas-fir overstory was killed in the fire, but a new forest has been established by planting, direct seeding, and some natural seeding. Canopy closure of th tree overstory is predicted before postfire year 30 (Lyon 1971).

Most of the preburn shrub species have resprouted, bu the relative importance of several species has been signi cantly modified. Before the fire, crown volume per acre Rocky Mountain maple was greater than all other shrub species. During the first 7 postfire years, however, Scou willow and maple were about equal in crown volume, an crown volume per acre of snowbrush ceanothus nearly s passed all other shrub species (Lyon 1971).

The Neal Canyon prescribed fire was judged to be suc cessful in all respects. Silvicultural objectives were achieved, wildlife habitat was significantly improved, an there was no apparent watershed damage. Lyon (1971) presents a theoretical model (fig. 16) to show that the preburn forest community description can be used to predict postfire community structure and long-term development pattern.

Lyon (1971) properly cautions that sites with depaupe ate vegetal communities and fragile soils do not recover from burning in the relatively short-term periods suggested at Neal Canyon.

The increased flammability of both logging slash and standing, living and dead trees containing witches'-broo was clearly demonstrated by the fire at Neal Canyon. Alexander and Hawksworth (1975) describe the situatio

> Flaming witches-brooms 2 to 3 feet in diameter were carried aloft in the convection column, fell and caused spot fires from 6 to 8 chains outside the control lines. The dense, heavy witches-brooms "exploded" on impact with the ground and almost instantly spread flames over a 12- to 15-foot circular area. In addition, some burning brooms rolled down hillsides after landing, causing further fire spread.

FIRE GROUP FIVE: MOIST DOUGLAS-FIR HABITAT TYPES

ADP code	Habitat type-phase (Steele and others 1981)	Physiographic sections (Steele and others 1981)
396	*Pseudotsuga menziesii/ Berberis repens* h.t. - *Berberis repens* phase (PSME/BERE-BERE), Douglas-fir/Oregon grape - Oregon grape phase	Southern Batholith
375	*Pseudotsuga menziesii/ Osmorhiza chilensis* h.t. (PSME/OSCH), Douglas-fir/mountain sweet-root	Southern Batholith and Wallowa-Seven Devils
280	*Pseudotsuga menziesii/ Vaccinium globulare* h.t. (PSME/VAGL), Douglas-fir/blue huckleberry	Incidental in Southern Batholith and Salmon Uplands
393	*Pseudotsuga menziesii/Acer glabrum* h.t. - *Acer glabrum* phase (PSME/ACGL-ACGL), Douglas-fir/mountain maple - mountain maple phase	Southern Batholith and Challis
265	*Pseudotsuga menziesii/ Physocarpus malvaceus* h.t. - *Pseudotsuga menziesii* phase (PSME/PHMA-PSME), Douglas-fir/ninebark - Douglas-fir phase	Challis and Open Northern Rockies
290	*Pseudotsuga menziesii/ Linnaea borealis* h.t. (PSME/LIBO), Douglas-fir/twinflower	Incidental in Salmon Uplands
250	*Pseudotsuga menziesii/ Vaccinium caespitosum* h.t. (PSME/VACA), Douglas-fir/dwarf huckleberry	Incidental in Southern Batholith and Salmon Uplands

Vegetation

Douglas-fir is the indicated climax species in all habitat types. It is also the major seral species. Ponderosa pine can be a major seral species within the PSME/BERE-BERE and PSME/OSCH h.t.'s. Except for the greater occurrence of Douglas-fir, these habitat types could be included in Fire Group Three. Similarly, lodgepole pine can be a major seral species at cool and moist extremes. Aspen and accidental individuals of subalpine fir occur at some sites.

Fire Group Five sites are more moist than Fire Group Four sites, so that fully stocked, closed-canopy forests develop (fig. 17). Regeneration following disturbance may, however, be slow due to competition from shrubs or pinegrass and elk sedge. Common shrubs include ninebark, mountain maple, serviceberry, Oregon grape, rose, mountain snowberry, blue huckleberry, dwarf huckleberry, twinflower, and bearberry. In addition to pinegrass and elk sedge, common herbs include bigleaf sandwort, Wilcox's penstemon, mountain sweet-root, heartleaf arnica, showy aster, false Solomon's seal, and western meadowrue.

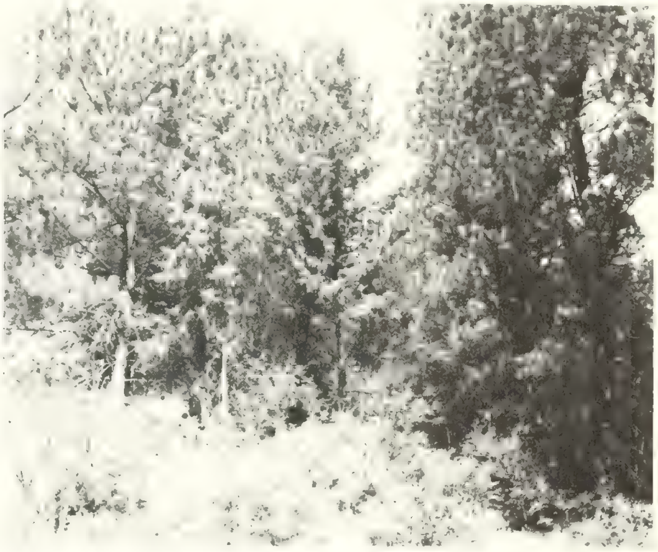


Figure 17—A productive PSME/PHMA h.t. in an early successional stage, near Roaring River, Boise National Forest.

Forest Fuels

Depending on stand density, down, dead, woody fuels vary between light and moderate; a range of about 5 to 20 tons/acre (1 to 5 kg/m^2), although heavier fuel loads may occur. The most hazardous conditions occur in relatively closed stands with dense Douglas-fir understories. These stands are usually characterized by relatively large amounts of downed twigs and small branchwood less than 3 inches in diameter. Downed as well as standing dead trees resulting from dwarf mistletoe mortality and associated witches'-brooms may add greatly to fuel loads and corresponding fire hazard.

If dense understories are absent, fire hazard is reduced accordingly; however, the density of overstory trees and the presence of dead branches near the ground create a crown fire potential under severe burning conditions.

Fuel conditions in stands dominated by lodgepole pine tend to be less hazardous than stands dominated by Douglas-fir. Ladder fuels are much less prevalent, so the probability of fire going from the forest floor to the crowns is not as great.

Role of Fire

In western Montana, Freedman and Habeck (1984) estimated the historic mean fire-free interval for sites belonging to the PSME/SYAL-CARU and PSME/VACA h.t.'s to be about 25 years, with an estimated range of

5 to 67 years (Arno 1976; Gabriel 1976). Arno (1980) further suggests that forests in the Douglas-fir series experience a range of fire severity resulting in a mosaic of fire effects.

In this group, fires of low-to-moderate severity would open dense stands of pole-sized or larger trees. Subsequent light burns would maintain these stands in a parklike condition. Long fire-free intervals may result in overstocked stands or open stands with dense understories, creating conditions that might eventually lead to a severe stand-replacing burn.

In these stands fire is an important factor in maintaining wildlife habitat. Fire opens up stands by killing overstory trees, reduces competition by removing understories and rejuvenates sprouting plants through top kill, thus increasing the availability of browse and forage.

As indicated in Fire Group Two, wildfire has played an important role in the distribution of Douglas-fir and its dwarf mistletoe. The patchy distribution of dwarf mistletoe is due, in large part, to fire history (Tinnin and Knutson 1973; Alexander and Hawksworth 1975).

Forest Succession

The theoretical climax stand is a multistoried Douglas-f stand. Fire maintains many stands in an open, seral conc tion in the Salmon Uplands, Southern Batholith, and Wallowa-Seven Devils physiographic sections as shown ir figure 18 (subsequent numbers in this section refer to fig. 18). Following a stand-replacing fire (No. 1) grass, forbs, and shrubs will dominate the site. If aspen is present, it resprouts and quickly dominates wherever survivi rootstock exists. Any fire will perpetuate this state (No. 2); if a shrub or aspen canopy develops, conifer esta lishment is slow. Douglas-fir seedlings establish on most sites, in the absence of fire, along with ponderosa pine a low elevations. Lodgepole pine will also establish on som colder sites, including low-elevation frost pockets, and ca dominate the site if a seed source is available. Any fire i the seedling/sapling state (No. 3) returns the site to gras forbs, and shrubs.

A severe fire in the pole stage (No. 4) will return the site to grass, forbs, and shrubs. If serotinous lodgepole pine is present, a stand of lodgepole may result. A light fire in a pole stand (No. 5) or a low-to-moderate fire in a large-pole or mature stand (No. 6) thins the stand, favoring ponderosa pine if present, resulting in an open stand of mixed species. Severe fire (No. 7) returns the site to herbs and shrubs. Without fire a climax Douglas-fir fore develops.

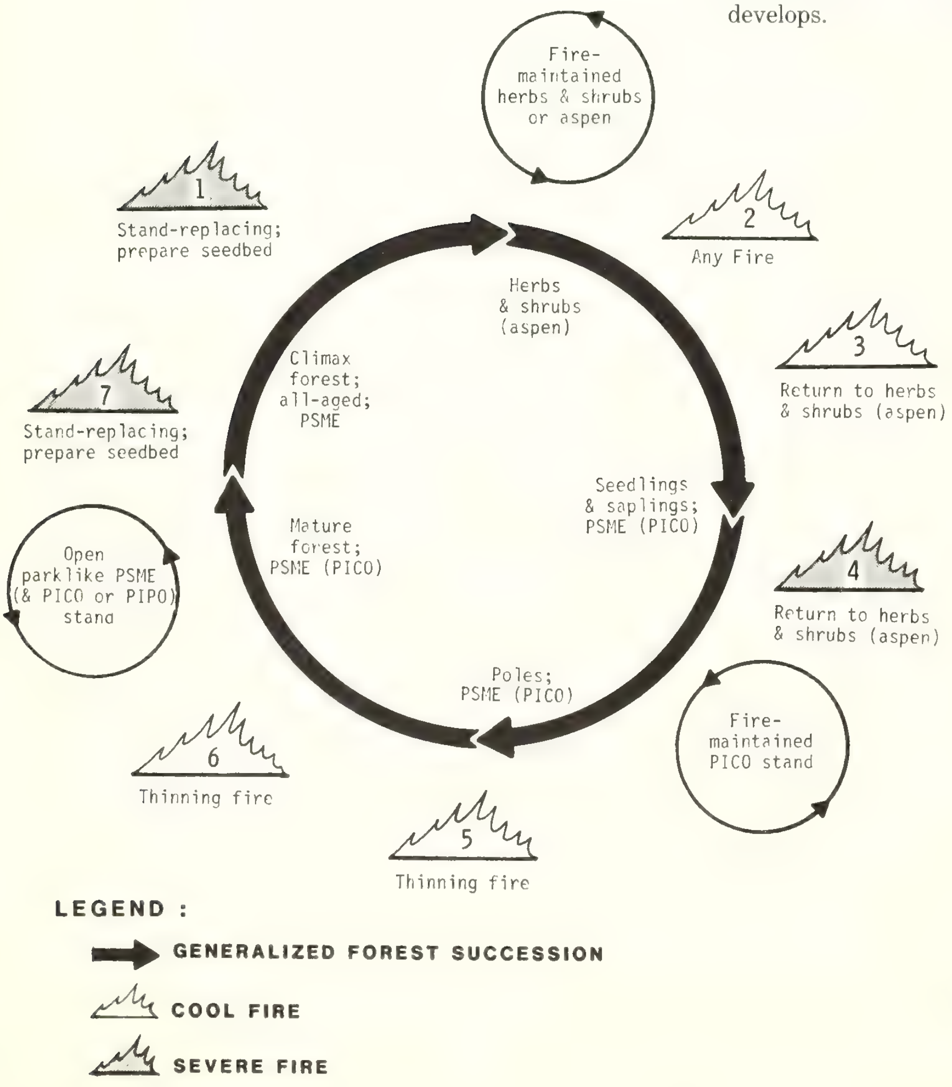

Fire-maintained herbs & shrubs or aspen
1
Stand-replacing; prepare seedbed
2
Any Fire
Herbs & shrubs (aspen)
3
Return to herbs & shrubs (aspen)
Climax forest; all-aged; PSME
7
Stand-replacing; prepare seedbed
Seedlings & saplings; PSME (PICO)
Open parklike PSME (& PICO or PIPO) stand
Mature forest; PSME (PICO)
4
Return to herbs & shrubs (aspen)
Poles; PSME (PICO)
Fire-maintained PICO stand
6
Thinning fire
5
Thinning fire
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 18—Generalized forest successi in Fire Group Five: moist Douglas-fir habitat types.

Group Five habitat types tend to support nearly pure stands of Douglas-fir or, at high elevations, mixed stands of Douglas-fir and lodgepole pine. Within its elevational range, ponderosa pine may mix with Douglas-fir. In cold air drainages all three species may be present. Ponderosa pine dominates some seral stands. Hypothetical successional pathways for stands with ponderosa pine as the dominate seral species are represented in figures 11 (see Fire Group Three) and 22 (see Fire Group Six). Most Fire Group Five stands follow the hypothetical successional pathways shown in figure 19.

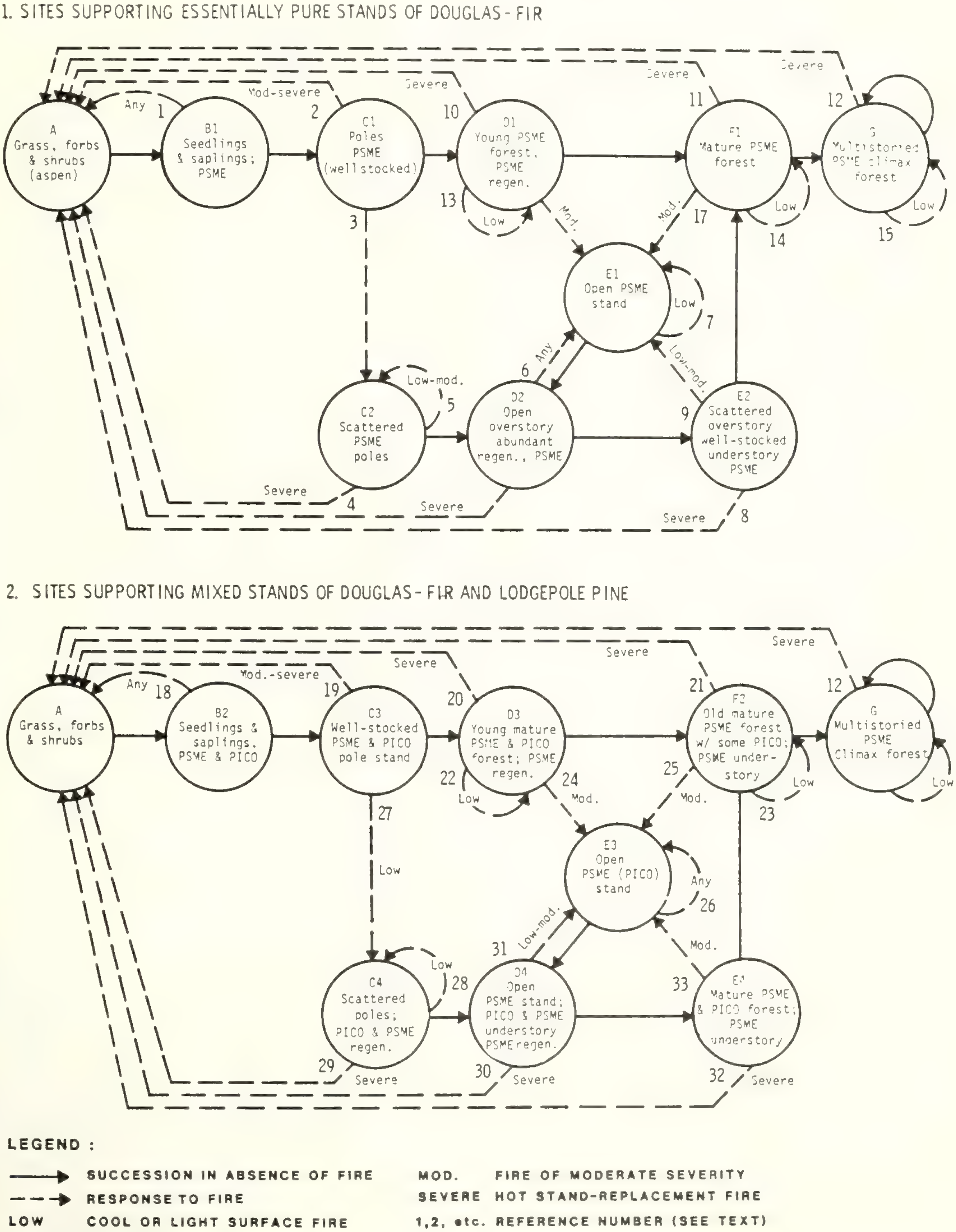

1. SITES SUPPORTING ESSENTIALLY PURE STANDS OF DOUGLAS-FIR
A Grass, forbs & shrubs (aspen)
B1 Seedlings & saplings; PSME
C1 Poles PSME (well stocked)
D1 Young PSME forest, PSME regen.
F1 Mature PSME forest
G Multistoried PSME climax forest
E1 Open PSME stand
C2 Scattered PSME poles
D2 Open overstory abundant regen., PSME
E2 Scattered overstory well-stocked understory PSME
Any 1
Mod-severe 2
3
Severe 4
Low-mod. 5
Any 6
Low 7
Severe 8
Low-mod. 9
Severe 10
Severe 11
Severe 12
Low 13
Low 14
Low 15
Mod. 17
Mod.
Severe
2. SITES SUPPORTING MIXED STANDS OF DOUGLAS-FIR AND LODGEPOLE PINE
A Grass, forbs & shrubs
B2 Seedlings & saplings. PSME & PICO
C3 Well-stocked PSME & PICO pole stand
D3 Young mature PSME & PICO forest; PSME regen.
F2 Old mature PSME forest w/ some PICO; PSME understory
G Multistoried PSME Climax forest
E3 Open PSME (PICO) stand
C4 Scattered poles; PICO & PSME regen.
D4 Open PSME stand; PICO & PSME understory PSME regen.
E4 Mature PSME & PICO forest; PSME understory
Any 18
Mod.-severe 19
Severe 20
Severe 21
Severe 12
Low 22
Low 23
Mod. 24
Mod. 25
Any 26
Low 27
Low 28
Severe 29
Severe 30
Low-mod. 31
Severe 32
Mod. 33
Low
LEGEND:
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 19—Hypothetical fire-related successional pathways for Fire Group Five habitat types.

Arno and others (1985) show the sequence of seral community types developing after stand-destroying wildfire and clearcutting with broadcast burning, mechanical scarification, or no followup treatment within moist PSME/PHMA and PSME/VAGL-XETE h.t.'s in western Montana.

Fire Management Considerations

Fire Group Five stands are quite variable, depending on site conditions, stand history, and successional stage. Fire management considerations must, therefore, be attuned to this variation.

Wildfire Supression—Protection from unwanted fire may be a major fire management consideration in stands where combinations of live and dead fuels result in a severe fire behavior potential. It may be difficult and impractical to abate the fire hazard in such stands except in conjunction with timber harvest operations. Preattack planning coupled with rapid detection and initial attack may be the only reasonable means to deal with such situations until such time as harvest operations can be scheduled.

Hazard Reduction and Site Preparation—Fire can be used to prepare seedbeds and reduce hazard following logging including the elemination of mistletoe-infected residual trees. Care must be taken to control fire intensity when burning in partially cut stands. The diameter of residual Douglas-fir trees and their branching habit will dictate, to a large extent, the kind of fire that can be prescribed. Guidelines for fuel consumption and duff reduction developed by Brown and others (1985) should be consulted.

On some sites, light or moderate fires may result in unusually high coverages of pinegrass. When this condition develops careful site preparation is required for successful regeneration of conifers (Steele and others 1981).

Wildlife Management—Fire use considerations for wildlife management are similar to those discussed for Fire Group Four. Some Fire Group Five sites are represented in the prescribed fire case study presented in that discussion. Many Fire Group Five sites are excellent berry producers for bear, grouse, and humans. Spring burning can often increase berry production by top-killing old shrubs, thereby stimulating resprouting (Miller 1977).

FIRE GROUP SIX: GRAND FIR HABITAT TYPES

ADP code	Habitat type-phase (Steele and others 1981)	Physiographic section (Steele and others 1981)
585	*Abies grandis/Calamagrostis rubescens* h.t. (ABGR/CARU), grand fir/pinegrass	Wallowa-Seve Devils and Southern Bat
505	*Abies grandis/Spiraea betulifolia* h.t. (ABGR/SPBE), grand fir/white spirea	Wallowa-Seve Devils and Southern Bath
527	*Abies grandis/Acer glabrum* h.t. - *Physocarpus malvaceus* phase (ABGR/ACGL-PHMA), grand fir/mountain maple - ninebark phase	Wallowa-Seven Devils and Southern Bath
526	*Abies grandis/Acer glabrum* h.t. - *Acer glabrum* phase (ABGR/ACGL-ACGL), grand fir/mountain maple - mountain maple phase	Wallowa-Seven Devils and Southern Batho
591	*Abies grandis/Linnaea borealis* h.t. - *Linnaea borealis* phase (ABGR/LIBO-LIBO), grand fir/twinflower - twinflower phase	Wallowa-Seven Devils and Southern Batho
592	*Abies grandis/Linnaea borealis* h.t. - *Xerophyllum tenax* phase (ABGR/LIBO-XETE), grand fir/twinflower - beargrass phase	Salmon Uplands
515	*Abies grandis/Vaccinium globulare* h.t. (ABGR/VAGL), grand fir/blue huckleberry	Wallowa-Seven Devils and Southern Batholi
510	*Abies grandis/Xerophyllum tenax* h.t. (ABGR/XETE), grand fir/beargrass	Salmon Uplands and Wallowa-Seven Devils
593	*Abies grandis/Linnaea borealis* h.t. - *Vaccinium globulare* phase (ABGR/LIBO-VAGL), grand fir/twinflower - blue huckleberry phase	Wallowa-Seven Devils and Southern Batholit
511	*Abies grandis/Coptis occidentalis* h.t. (ABGR/COOC), grand fir/western goldthread	Salmon Uplands
520	*Abies grandis/Clintonia uniflora* h.t. (ABGR/CLUN), grand fir/queencup beadlily	Wallowa-Seven Devils and Southern Batholith

egetation

The highly productive habitat types included in this fire ·oup are typically more moist than Douglas-fir habitat ·pes and warmer than subalpine fir habitat types. They ·e found between 3,400 ft (1,040 m) and 6,500 ft ,980 m) in elevation and support a very diverse flora ·teele and others 1981). Seral communities include ·nderosa pine, lodgepole pine, Douglas-fir, Engelmann ·ruce, western larch, and aspen. Undergrowth species are also varied. Shrubs include white spirea, pyramid spirea, blue huckleberry, common snowberry, Utah honeysuckle, mountain maple, serviceberry, Scouler willow, ninebark, rose, twinflower, and myrtle pachistima. Herbs may include pinegrass, elk sedge, Ross sedge, heartleaf arnica, western pipsissewa, western meadowrue, sweetroot, beargrass, strawberry, Nevada peavine, pathfinder, Hooker fairybells, western goldthread, queencup beadlily, sidebells pyrola, Solomonplume, and Sitka valerian. See figure 20 for examples of Fire Group Six grand fir stands.

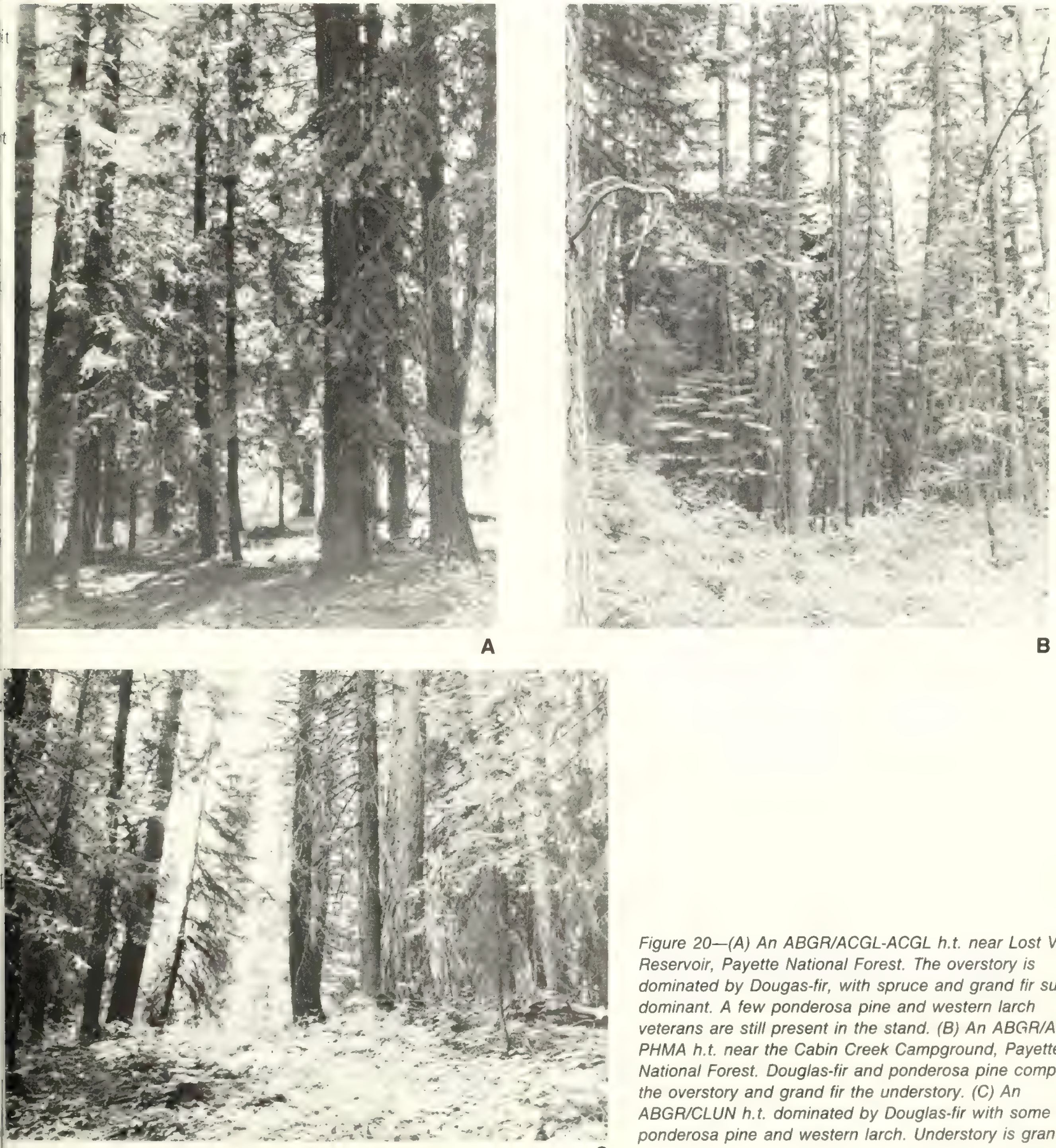


Figure 20—(A) An ABGR/ACGL-ACGL h.t. near Lost Valley Reservoir, Payette National Forest. The overstory is dominated by Dougas-fir, with spruce and grand fir subdominant. A few ponderosa pine and western larch veterans are still present in the stand. (B) An ABGR/ACGL-PHMA h.t. near the Cabin Creek Campground, Payette National Forest. Douglas-fir and ponderosa pine comprise the overstory and grand fir the understory. (C) An ABGR/CLUN h.t. dominated by Douglas-fir with some ponderosa pine and western larch. Understory is grand fir.

Forest Fuels

Quantitative descriptions of fuel loadings on central Idaho grand fir habitat types are lacking. Downed, woody fuel loadings on similar habitat types inventoried by Fischer (1981b) in western Montana ranged between about 13 and 38 tons/acre. The heavier loadings tended to occur in very moist streamside locations. Drier upland sites varied between 13 and 20 tons/acre. Brown and See (1981) show total downed woody fuel loadings averaging about 16 tons/acre (3.6 kg/m^2) within the ABGR/XETE h.t. and about 20 tons/acre (4.5 kg/m^2) within the ABGR/CLUN h.t. in western Montana and northern Idaho National Forests.

Live fuels in the form of understory fir and pine can add greatly to the crown fire hazard, especially under severe burning conditions. The often luxuriant undergrowth of shrubs and moist-site forbs may retard fire spread under normal summertime moisture conditions.

Role of Fire

Detailed information about the presettlement fire history of central Idaho grand fir stands is scarce. Fire has, nonetheless, altered these forests (Steele and others 1981). The dominance of seral species on drier sites and their presence in most stands, suggests fire's role. On drier grand fir sites frequent surface fires maintained open stands dominated by fire-tolerant ponderosa pine along with some Douglas-fir. Hall (1976, 1980) estimates that natural underburns occurred every 10 years in a mixed conifer-pinegrass forest in the Blue Mountains of Oregon. Part of this mixed conifer-pinegrass community is similar to those of the ABGR-CARU h.t. (Steele and others 1981).

On cooler and wetter sites, fires were less frequent. Fires of low-to-moderate severity favored open, seral stands of ponderosa pine, Douglas-fir, larch, and possibly lodgepole pine. Long fire-free intervals, however, allowed grand fir to dominate and form a closed canopy. Following severe, stand-replacing fires, persistent shrubs or pinegrass dominate some sites when conifers fail to establish. The mean fire interval for grand fir habitat types on the Nez Perce National Forest in north-central Idaho was estimated to be 70 to 120 years (Arno 1980).

Forest Succession

The theoretical Fire Group Six climax forest consists of all-aged grand fir and some incidental subalpine fir. The more common old-growth or near-climax stands usually contain some longer lived midtolerant species. The general path of succession is depicted in figure 21 (subsequent numbers in this section refer to fig. 21).

In this fire group, the initial herb and shrub community can persist if conifer regeneration is not prompt. Fire in this stage or during the seedling and sapling stage (Nos. 1 and 2), maintains a thick sod of pinegrass in the dry habitat types or a dense layer of shrubs in some of the moist habitat types. The composition of the initial stand is variable. At high elevations or in frost pockets lodgepole pine may dominate as it does in Fire Group Seven. At low elevations on south and west slopes, ponderosa pine may be the first and essentially the only conifer to establish on the site. Douglas-fir and other conifers will regenerate in sheltered microsites and eventually in the shade of the ponderosa pine. On less harsh sites a mixed conifer stand establishes with ponderosa pine, western larch, Douglas-fir, lodgepole pine, spruce, grand fir, and even an occasional subalpine fir seedling.

A severe fire in a pole stand (No. 3) returns the site to herbs and shrubs. A surface fire (No. 4) thins the stand, favoring ponderosa pine, Douglas-fir, and if within its range, larch. Repeated low-intensity surface fires maintain an open stand of ponderosa pine and Douglas-fir with an understory of true firs and spruce. Low-to-moderate fires (No. 5) in a mature mixed conifer forest result in a similar, fire-maintained seral stand. A severe fire (No. 6) returns the site to herbs and shrubs. In the absence of fire, grand fir, spruce, and some subalpine fir dominate the understory in old-growth stands because ponderosa pine and Douglas-fir will have difficulty regenerating under the dense canopy. As it matures, grand fir develops a thicker, more fire-resistant bark. Occasional low-to-moderate fires (No. 7) create openings in the canopy and expose mineral soil. This allows some reproduction of all species and maintains the mixed condition. The less shade-tolerant seral species will be lost from the near-climax stand in the absence of fire, leaving true firs and spruce. When fire does occur in the near-climax or the climax forest (No. 8) stand replacement is likely.

Ponderosa pine and Douglas-fir are seral species in the warm and dry habitat types of this fire group. The ABGR/CARU, ABGR/SPBE, ABGR/ACGL-PHMA, ABGR/ACGL-ACGL, and ABGR/LIBO-LIBO h.t.'s all fit into this warm, dry subgroup. The ABGR/LIBO-LIBO h.t. may support some lodgepole pine in seral stands, but ponderosa pine and Douglas-fir will dominate. Succession in these habitat types is considered in part 1 of figure 21. The remaining habitat types in this fire group are generally cool and moist, hence ponderosa pine is a minor seral species while lodgepole pine and Engelmann spruce dominate. Western larch may occur as a minor seral species or, within the ABGR/CLUN h.t., a major seral species on the Payette National Forest. Stands belonging to the ABGR/VACA are included in Fire Group Seven, bu some stands respond to fire as do Fire Group Six stands. This cool, moist subgroup consists of the ABGR/VAGL, ABGR/LIBO-XETE, ABGR/CLUN, ABGR/XETE, and ABGR/COOC h.t.'s. Hypothetical successional pathways for stands within these habitat types are represented in part 2 of figure 22.

Fire Management Considerations

Group Six sites have the highest potential for growing timber. Protection from fire damage is, consequently, an important fire management task in managed stands. This task is often complicated by the presence of hazardous fu conditions which in many instances are the result of the successful fire suppression efforts of the past. In seral stands dominated by large ponderosa pine and Douglas-fi dense fir-dominated understories can be burned during relatively mild conditions thereby lessening the chance of stand-destroying wildfires under severe burning condi-

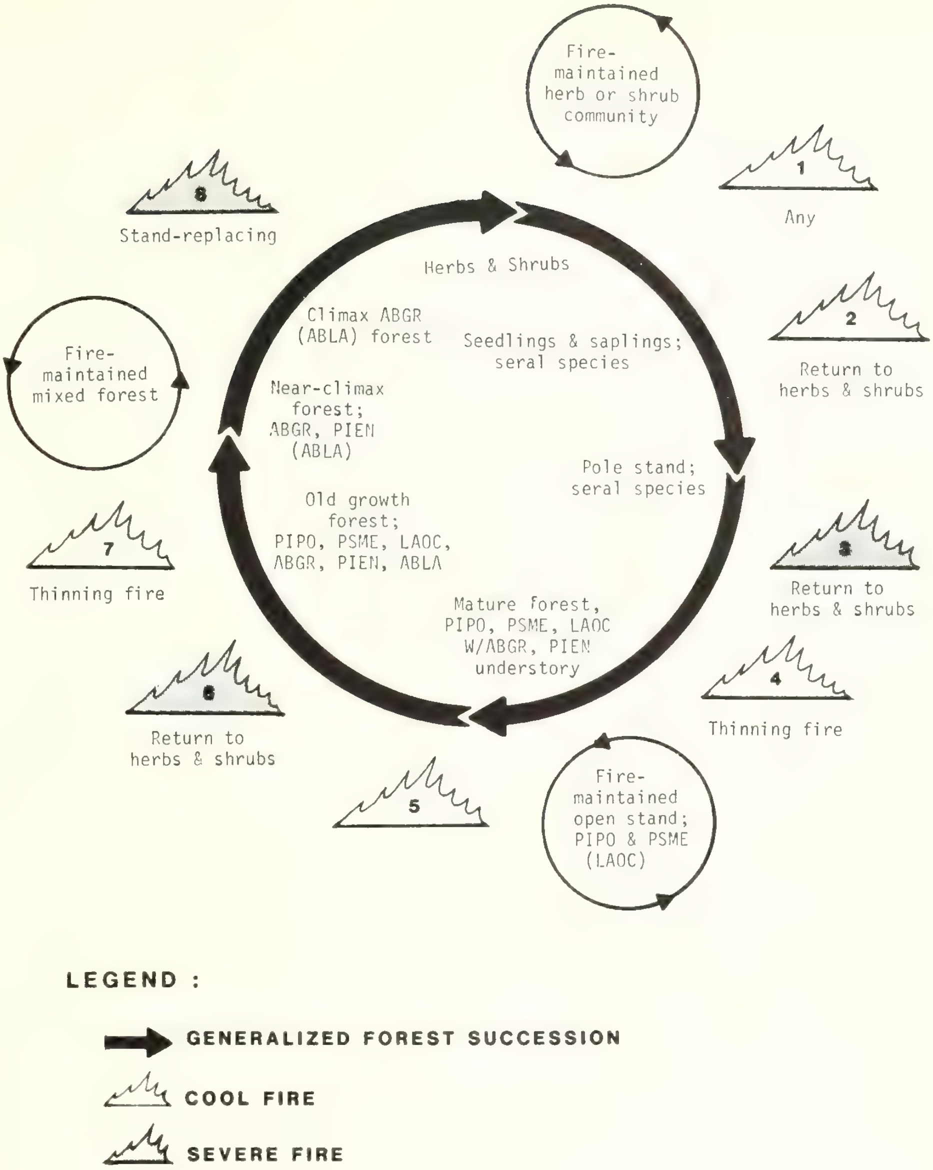

Fire-maintained herb or shrub community
1
Any
2
Return to herbs & shrubs
3
Return to herbs & shrubs
4
Thinning fire
Fire-maintained open stand; PIPO & PSME (LAOC)
5
6
Return to herbs & shrubs
7
Thinning fire
Fire-maintained mixed forest
8
Stand-replacing
Herbs & Shrubs
Seedlings & saplings; seral species
Pole stand; seral species
Mature forest, PIPO, PSME, LAOC W/ABGR, PIEN understory
Old growth forest; PIPO, PSME, LAOC, ABGR, PIEN, ABLA
Near-climax forest; ABGR, PIEN (ABLA)
Climax ABGR (ABLA) forest
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 21—Generalized forest succession in Fire Group Six: grand fir habitat types.

ons. Many unproductive stands, however, would probably enefit from being destroyed by fire.

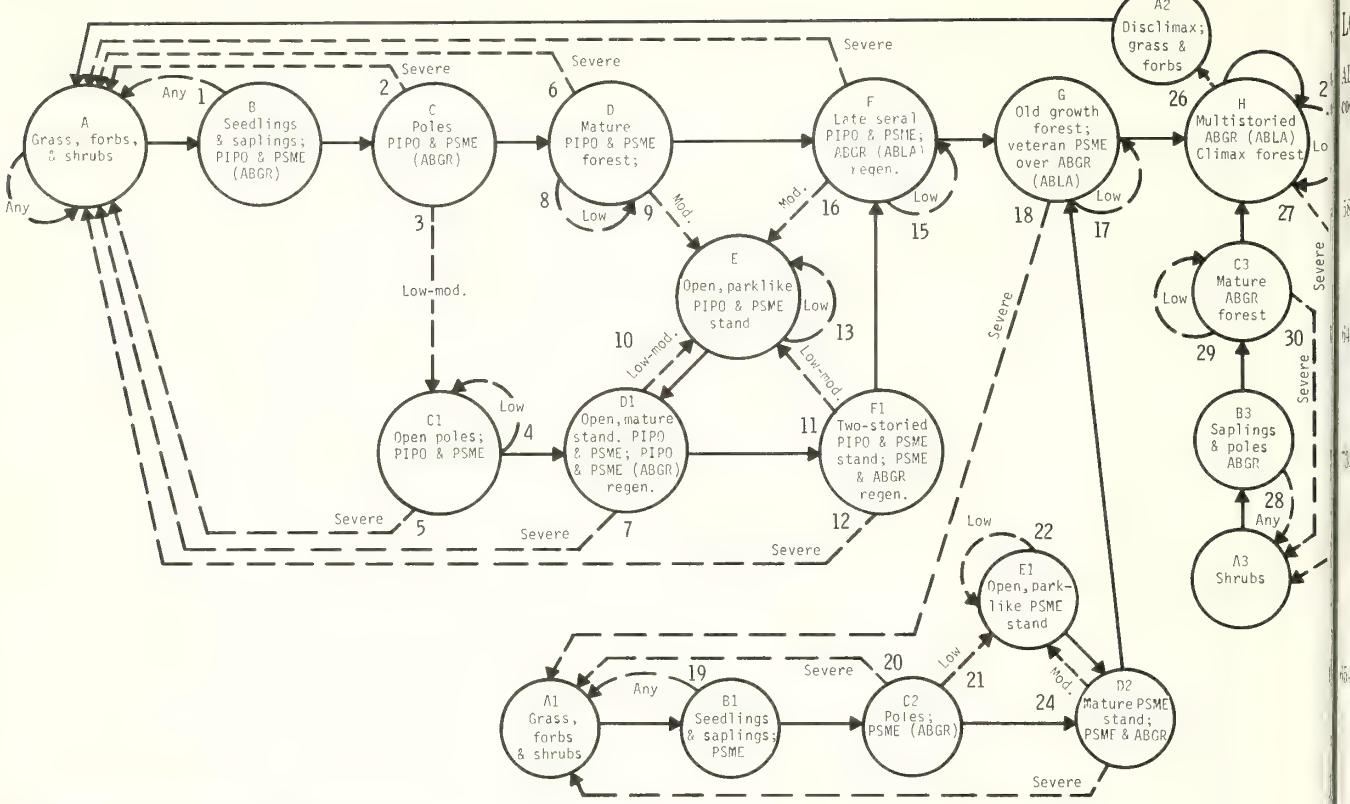
Prescribed fire can be used following cutting to reduce esh logging slash, accumulated woody debris, and ndesirable understory trees. Used in conjunction with earcutting, broadcast fire can, in addition to fuel reducon, provide a favorable seedbed for ponderosa pine and estern larch. Broadcast burning may be inappropriate hen partial cutting leaves heat-susceptible grand fir in e overstory. Large-diameter grand fir may, however, rvive prescribed understory burning if slash and other oody debris is cleared from the base of crop trees and ame lengths are controlled to minimize crown scorch.

Logging and burning on many Group Six sites often sult in a dense stand of tall shrubs that may dominate e site for at least 20 years. This may or may not be a sirable response, depending on land management objectives for the site. The lush shrubbery can provide favorable browse for big game animals. If immediate domination of the site by shrubs is undesirable, the preharvest prescribed burning (Martin 1982), described in Fire Group Three, may be an appropriate treatment.

Ponderosa pine stands can be maintained on Group Six grand fir sites by periodic underburning once the pine has attained a diameter of 5 inches or more as described in Fire Group Three. Periodic prescribed fires designed to favor pine over fir will lessen the risk of serious losses from western spruce budworm and the tussock moth.

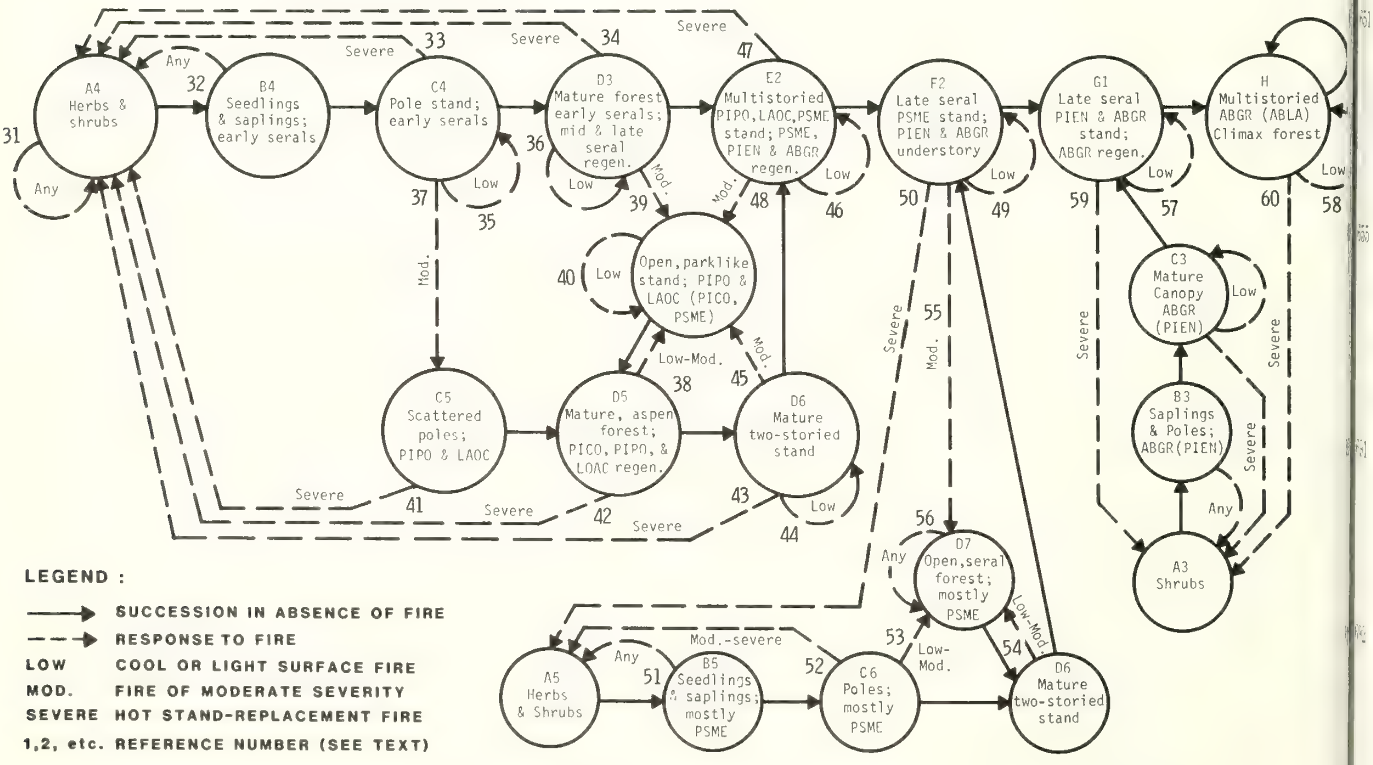
In some Group Six habitat types, blue huckleberry is an important food source for bear, grouse, and humans. Berry production can be maintained or increased by periodic spring burning (Miller 1977), as described in Fire Group Five, and by maintaining open stand conditions.

1. SUCCESSION WITH PONDEROSA PINE AND DOUGLAS-FIR



A Grass, forbs, & shrubs
B Seedlings & saplings; PIPO & PSME (ABGR)
C Poles PIPO & PSME (ABGR)
D Mature PIPO & PSME forest;
F Late seral PIPO & PSME; ABGR (ABLA) regen.
G Old growth forest; veteran PSME over ABGR (ABLA)
H Multistoried ABGR (ABLA) Climax forest
A2 Disclimax; grass & forbs
E Open, parklike PIPO & PSME stand
C1 Open poles; PIPO & PSME
D1 Open, mature stand. PIPO & PSME; PIPO & PSME (ABGR) regen.
F1 Two-storied PIPO & PSME stand; PSME & ABGR regen.
C3 Mature ABGR forest
B3 Saplings & poles ABGR
A3 Shrubs
E1 Open, park-like PSME stand
A1 Grass, forbs & shrubs
B1 Seedlings & saplings; PSME
C2 Poles; PSME (ABGR)
D2 Mature PSME stand; PSME & ABGR
Any 1
Any
Severe 2
Severe 6
Severe
3 Low-mod.
8 Low 9
Mod.
Mod. 16
Low 15
18 Low 17
26
27
Low 13
10 Low-mod.
Low-mod.
Low 4
11
Severe 5
Severe 7
Severe 12
Severe
Low 29
30 Severe
Severe
28 Any
Low 22
19 Any
Severe 20
Low 21
Mod. 24
Severe

2. SUCCESSION WITH MIXED SERAL STANDS



A4 Herbs & shrubs
B4 Seedlings & saplings; early serals
C4 Pole stand; early serals
D3 Mature forest early serals; mid & late seral regen.
E2 Multistoried PIPO, LAOC, PSME stand; PSME, PIEN & ABGR regen.
F2 Late seral PSME stand; PIEN & ABGR understory
G1 Late seral PIEN & ABGR stand; ABGR regen.
H Multistoried ABGR (ABLA) Climax forest
Open, parklike stand; PIPO & LAOC (PICO, PSME)
C5 Scattered poles; PIPO & LAOC
D5 Mature, aspen forest; PICO, PIPO, & LAOC regen.
D6 Mature two-storied stand
C3 Mature Canopy ABGR (PIEN)
B3 Saplings & Poles; ABGR (PIEN)
A3 Shrubs
D7 Open, seral forest; mostly PSME
A5 Herbs & Shrubs
B5 Seedlings & saplings; mostly PSME
C6 Poles; mostly PSME
D6 Mature two-storied stand
31 Any
Any 32
Severe 33
Severe 34
Severe 47
37 Mod.
Low 35
36
Low 39 Mod.
Mod. 48
Low 46
50
Low 49
59
Low 57
60
Low 58
40 Low
Low-Mod. 38
45 Mod.
Severe 41
Severe 42
Severe 43
Low 44
Severe 55 Mod.
56 Any
Low
Severe
Severe
Severe
Any
Any 51
Mod.-severe 52
53 Low-Mod.
54 Low-Mod.
LEGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 22—Hypothetical fire-related successional pathways for Fire Group Six habitat types.

FIRE GROUP SEVEN: COOL HABITAT TYPES USUALLY DOMINATED BY LODGEPOLE PINE

ADP ode	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
580	*Abies grandis/Vaccinium caespitosum* h.t. (ABGR/VACA), grand fir/dwarf huckleberry	Southern Batholith
640	*Abies lasiocarpa/Vaccinium caespitosum* h.t. (ABLA/VACA), subalpine fir/dwarf huckleberry	Southern Batholith and Salmon Uplands
732	*Abies lasiocarpa/Vaccinium scoparium* h.t. - *Vaccinium scoparium* phase (ABLA/VASC-VASC), subalpine fir/grouse whortleberry - grouse whortleberry phase	Southern Batholith, Challis, Salmon Uplands, and Open Northern Rockies
54	*Abies lasiocarpa/ Calamagrostis canadensis* h.t. - *Vaccinium caespitosum* phase (ABLA/CACA-VACA), subalpine fir/bluejoint - dwarf huckleberry phase	Southern Batholith
51	*Abies lasiocarpa/ Calamagrostis canadensis* h.t. - *Calamagrostis canadensis* phase (ABLA/CACA-CACA), subalpine fir/bluejoint - bluejoint phase	Salmon Uplands and Southern Batholith
55	*Abies lasiocarpa/ Calamagrostis canadensis* h.t. - *Ledum glandulosum* phase (ABLA/CACA-LEGL), subalpine fir/ bluejoint - Labrador-tea phase	Challis, Southern Batholith, and Salmon Uplands
91	*Abies lasiocarpa/ Xerophyllum tenax* h.t. - *Vaccinium globulare* phase (ABLA/XETE-VAGL), subalpine fir/beargrass - blue huckleberry phase	Southern Batholith, Salmon Uplands, ans Open Northern Rockies
92	*Abies lasiocarpa/ Xerophyllum tenax* h.t. - *Vaccinium scoparium* phase (ABLA/XETE-VASC), subalpine fir/ beargrass - grouse whortleberry phase	Salmon Uplands
694	*Abies lasiocarpa/ Xerophyllum tenax* h.t. - *Luzula hitchcockii* phase (ABLA/XETE-LUHI), subalpine fir/beargrass - smooth woodrush phase	Salmon Uplands
721	*Abies lasiocarpa/Vaccinium globulare* h.t. - *Vaccinium scoparium* phase (ABLA/VAGL-VASC), subalpine fir/blue huckleberry - grouse whortleberry phase	Salmon Uplands
791	*Abies lasiocarpa/Carex geyeri* h.t. - *Carex geyeri* phase (ABLA/CAGE-CAGE), subalpine fir/elk sedge - elk sedge phase	Southern Batholith, Salmon Uplands, Challis, and Open Northern Rockies
750	*Abies lasiocarpa/ Calamagrostis rubescens* h.t. (ABLA/CARU), subalpine fir/pinegrass	Southern Batholith, Challis, and Open Northern Rockies
740	*Abies lasiocarpa/Alnus sinuata* (ABLA/ALSI), subalpine fir/Sitka alder	Incidental in Salmon Uplands
663	*Abies lasiocarpa/Linnaea borealis* h.t. - *Vaccinium scoparium* phase (ABLA/LIBO-VASC), subalpine fir/twinflower - grouse whortleberry phase	Southern Batholith, Salmon Uplands, and Open Northern Rockies
662	*Abies lasiocarpa/Linnaea borealis* h.t. - *Xerophyllum tenax* phase (ABLA/ LIBO-XETE), subalpine fir/twinflower - beargrass phase	Salmon Uplands, Southern Batholith, and Open Northern Rockies
731	*Abies lasiocarpa/Vaccinium scoparium* h.t. - *Calamagrostis rubescens* phase (ABLA/VASC-CARU), subalpine fir/ grouse whortleberry - pinegrass phase	Southern Batholith, Salmon Uplands, and Open Northern Rockies
905	*Pinus contorta/Festuca idahoensis* h.t. (PICO/FEID), lodgepole pine/Idaho fescue	Southern Batholith and occasionally in Challis, Salmon Uplands, and Open Northern Rockies
920	*Pinus contorta/Vaccinium caespitosum* c.t. (PICO/VACA c.t.), lodgepole pine/dwarf huckleberry	Southern Batholith

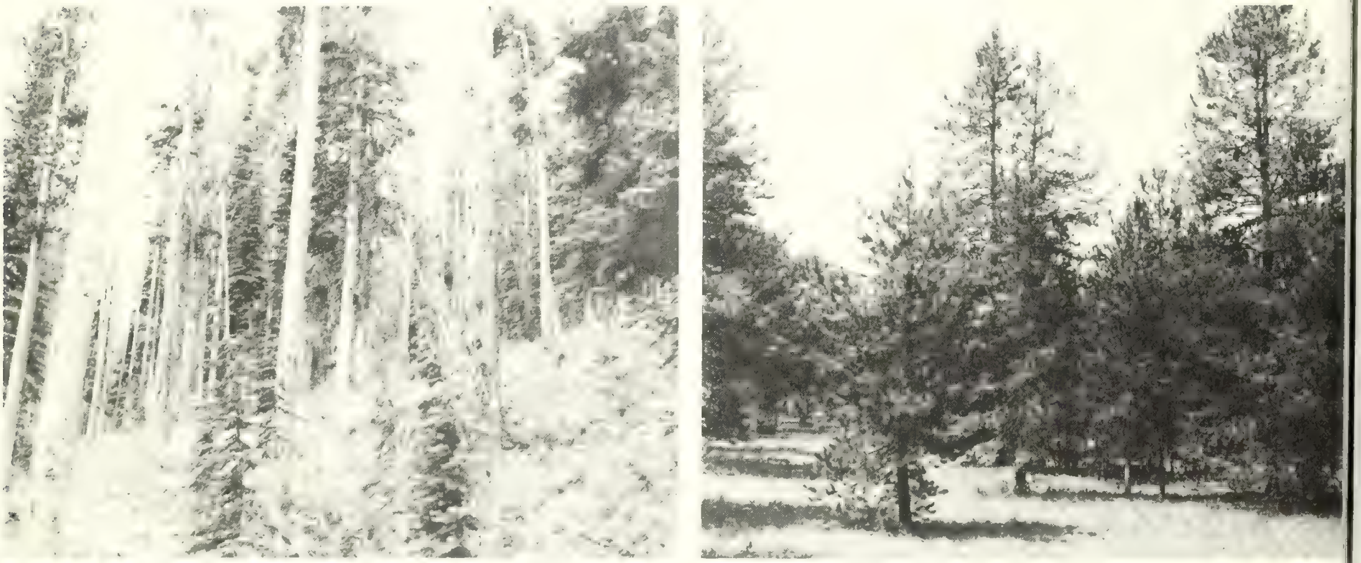
ADP code	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
940	*Pinus contorta/Vaccinium scoparium* c.t. (PICO/VASC c.t.), lodgepole pine/grouse whortleberry	Southern Batholith, Salmon Uplands, and Open Northern Rockies
955	*Pinus contorta/Carex geyeri* c.t. (PICO/CAGE c.t.), lodgepole pine/elk sedge	Southern Batholith

Vegetation

There are two subgroups in Fire Group Seven. One group consists of lodgepole pine habitat types and community types that support essentially pure stands of lodgepole pine, with little evidence that any other specie is climax. The other group contains grand fir and subalpine fir habitat types where succession is commonly dominated by lodgepole pine (fig. 23). Grand fir, spruce, and subalpine fir occur on most fir habitat types. Dougla fir is also found on some sites, and ponderosa pine is a minor seral species on some ABGR/VACA sites.

On some severe sites, lodgepole pine can be dominant and appear almost stable within the ABLA/VACA, ABLA/VASC, and sometimes ABLA/VAGL h.t.'s. These situations should be treated as belonging to the first subgroup of essentially pure lodgepole pine stands.

The most common shrubs are dwarf huckleberry, blue huckleberry, and grouse whortleberry. Other shrubs include Labrador-tea, myrtle pachistima, Sitka alder, mou tain snowberry, and big sagebrush. The herbaceous laye is frequently dominated by grass. Pinegrass, bluejoint, e sedge, or Idaho fescue may be predominant. Other common species include beargrass, smooth woodrush, twinflower, Ross sedge, western needlegrass, Hook viol heartleaf arnica, silvery lupine, Sitka valerian, and rosy pussytoes.



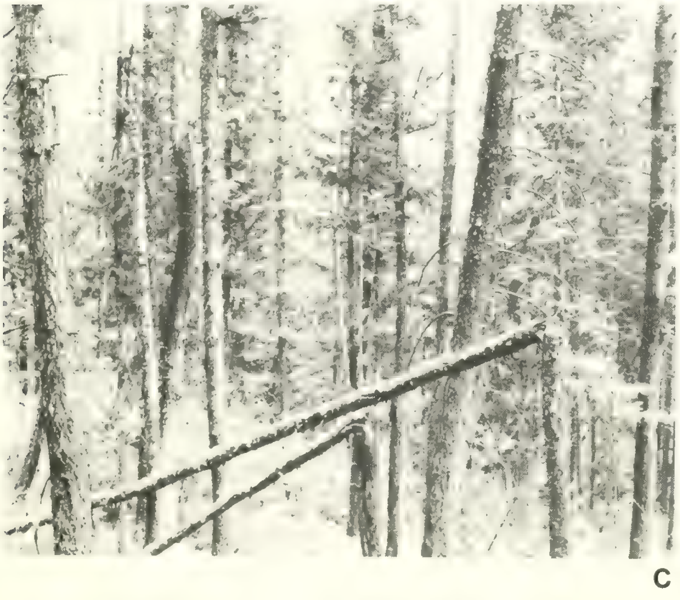


Figure 23—(A) An ABLA/CAGE h.t. alongside the Warren Wagon Road, Payette National Forest. The stand is dominated by lodgepole pine but undergoing invasion by subalpine fir. (B) A PICO/FEID h.t. northwest of Stanley, ID, Challis National Forest. (C) An ABLA/ALSI h.t. near the Lick Creek Road, Salmon National Forest.

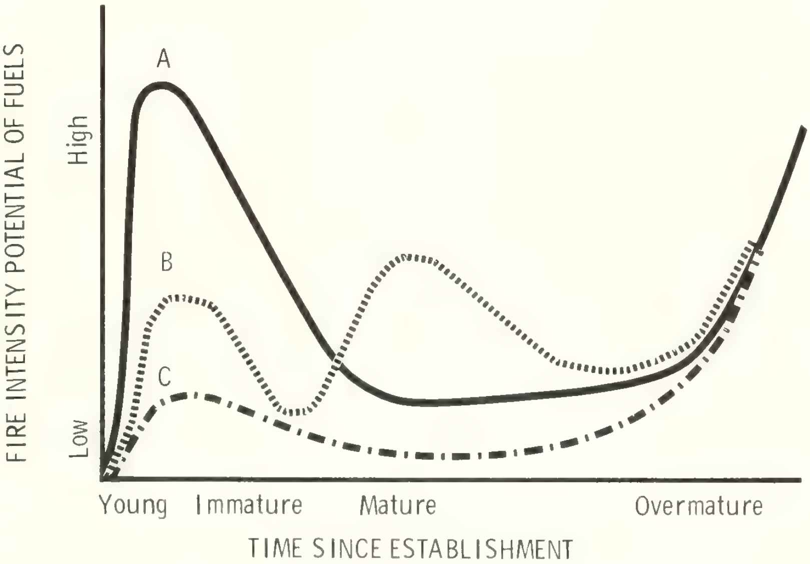
orest Fuels

Brown (1975) has characterized fuel cycles and fire azard in lodgepole pine stands, as shown in figure 24. urve A of that figure corresponds to what Muraro (1971) escribes as typical fire hazard in lodgepole pine where oung, especially dense stands are most hazardous. Least azardous are moderately dense-to-open advanced, imature, and mature stands. Hazard increases as stands ecome overmature and as ground fuels build up from ownfall and establishment of shade-tolerant species. urve C depicts conditions not uncommonly found. Ground uel quantities and fire potential remain relatively low roughout the life of the stand until it undergoes ecadence. Individual stands can vary anywhere between urves A and C during younger growth periods, and evelop higher fire potential at later periods of growth urve B).

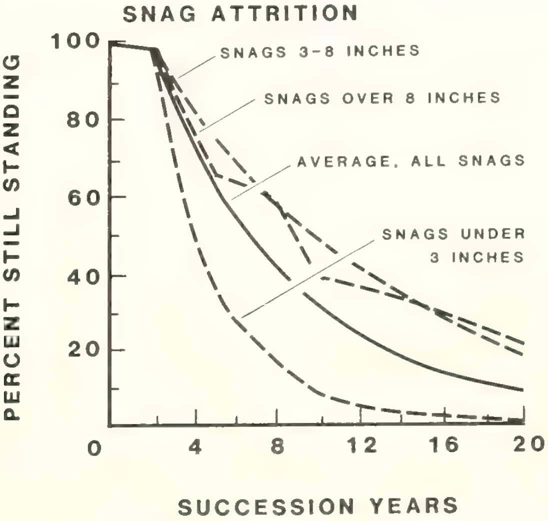
In a young lodgepole stand the snags created by the revious fire provide an immediate source of downfall. yon (1977, 1984) found that after 2 years with little windthrow, lodgepole pine snags on the Sleeping Child Burn (Bitterroot National Forest) fell at an annual rate of 13.4 percent (fig. 25). Overall, an average of 497 snags per acre was reduced to an average of 75 snags per acre after 15 years (table 6). After 21 years, nearly 93 percent of all snags had fallen (fig. 25).

Table 6—Average number of snags per acre by size class and year of count, Sleeping Child Burn, Bitterroot National Forest, MT (Lyon 1977) (totals may not agree because of rounding)

Size class	Year 1962	1963	1966	1969	1971	1976
Inches						
Under 3	266	265	96	41	28	4
3 to 8	159	156	124	103	85	50
8 to 12	64	62	40	36	24	19
Over 12	7	7	7	6	4	3
Total	497	390	268	186	141	75



ure 24—Fuel cycles and fire intensity potential lodgepole pine (Brown 1975).



ure 25—Percentage of lodgepole pine snags ll standing, by year and diameter class, Sleep- Child Burn, Bitterroot National Forest, MT, 62-82 (Lyon 1984).

Aside from fire-created snags, sources of downfall are natural thinning; snow breakage and windthrow of live trees; dwarf mistletoe-related mortality; and mountain pine beetle attack and subsequent mortality. Dwarf mistletoe often adds to the ground fuel and causes witches'-brooms that enhance vertical fuel continuity and thus increase the likelihood of ground fuels creating a "fire ladder" to burn out individual tree crowns (Brown 1975). The witches'-brooms also tend to trap fallen needles, thus increasing the scattering of vertically situated fine fuels, which are ideally situated for optional fire flammability (Alexander and Hawksworth 1975). Immature dwarf mistletoe-infested lodgepole pine stands have much more dead material on the ground, more stems, and more foliage near the ground, than comparable uninfested stands (Hawksworth and Hinds 1964). Mountain pine beetle attack is often the mechanism that causes the lodgepole stand to break up. Cumulative mortality during a mountain pine beetle epidemic (average duration about 11 years) frequently amounts to 85 percent or more of the large, 8-inch (20-cm) diameter trees in a lodgepole pine stand (Cole and Amman 1980).

Published fuel inventory data for central Idaho lodgepole pine stands are lacking. Data from Montana and northern Idaho indicate down, dead woody fuel loads of 3 to 35 tons/acre (0.7 to 8 kg/m^2) (Fischer 1981c; Brown and See 1981). As a general rule, central Idaho lodgepole pine stands are less heavily laden with downed, dead, woody fuel than are neighboring stands in Montana where fuel loadings in excess of 150 tons/acre (34 kg/m^2) have been reported (Mathews 1980).

Moderate to heavy fuel loads are much more likely to occur in seral stands of lodgepole pine than in climax stands in central Idaho. This is true for live fuels as well as dead, woody fuels. Dense understories of spruce and subalpine fir (or grand fir) develop beneath the overstory lodgepole pine within subalpine fir (or grand fir) habitat types. When sufficient surface fuels exist beneath such understories an effective fuel ladder is created and crown fire hazard is great.

The association between successional stage and fuel loading on lodgepole pine sites is reflected in table 7. The values in table 7 represent the results of fuel inventories on 36 stands belonging to the ABLA/VASC and ABLA/CAGE h.t.'s within the Teton Wilderness, western Wyoming (Oberheu and Mutch 1976). The recent burn stand condition was characterized by moderate to dense stocking of even-aged lodgepole pine seedlings or saplings, 3 to 40 years old. These stands contained heavy loadings of large-diameter, windthrown, fire-killed snags and very little duff. The even-aged lodgepole pine stands were characterized by dense, even-aged lodgepole, 85 to 140 years old, with closed or nearly closed canopies and evidence of some natural thinning in progress. Decay had reduced the heavy loading of down material from the previous fire. The transition stands were characterized by mostly mixed overstories of old-age lodgepole pine 230 to 250 years old, along with spruce and subalpine fir over spruce-fir understories. Increasingly large-diameter fuel loadings reflect the breakup of the lodgepole pine stand. The spruce-fir stands were characterized by overstories of subalpine fir and scattered, very large spruce, 250 years or more in age. Heavy fuel loads reflect the downing of dead lodgepole.

Role of Fire

Arno (1980) concluded that more frequent (generally between 25 and 50 years apart) low-to-medium severity surface fires were associated with lodgepole pine-dominated communities having dry summers. In areas with moist summers, fire was less frequent and more severe, with large stand-replacement fires more prevalent, although stand-replacement fires did occur to some extent in all areas where lodgepole pine was dominant.

Romme (1982) found that light surface fires on a high plateau west of Old Faithful in Yellowstone National Park spread slowly and covered only small areas before going out. Growth is slow on these unfavorable sites, and it takes over 300 years before fuel accumulations support fire. Then a severe stand-replacement crown fire would be most likely.

In central Idaho, the most persistent and possibly climax lodgepole pine stands occur in broad, high-elevation valley where its dominance appears to be related to its ability to withstand daily temperature extremes and fluctuating water tables (Steele and others 1981). These stands often consist of widely spaced trees with little undergrowth on gentle slopes; fire appears to be a minor factor. Lodgepole pine competes well with other tree species on sites with shallow granitic soils, where summer frosts are frequent and summer rainfall is low (Lotan and Perry 1983).

Table 7—Dead fuel loads associated with stands within the ABLA/VASC and ABLA/CAGE h.t.'s, Teton Wilderness, WY (source Oberheu and Mutch 1976)

Stand condition	Stand age	Downed, dead woody fuel by size classes (inches)							
		0-1/4	1/4-1	1-3	3+ sound	3+ rotten	Total	Litter	Duff
	Years	*Tons per acre*							
Recent burn	3-40	0.1	0.3	1.1	25.3	17.0	43.8	0.5	10.1
Even-aged lodgepole	85-140	.1	.5	1.0	4.2	2.8	8.6	1.2	28.9
Transition	230-250	.2	.8	1.9	12.2	9.5	24.6	1.5	33.2
Spruce-fir	250+	.2	.9	2.3	10.2	14.2	27.8	1.0	37.3

In subalpine fir and grand fir habitat types, where dgepole pine is the dominant seral species, fire-induced tands of lodgepole pine cover large areas, and the educed seed sources of other conifers delay their replaceent (Steele and others 1981). Repeated wildfire further epletes seed sources of other conifers in the area. This ads to even more uniform stands of lodgepole pine, hich become increasingly flammable. Fuels build up in ature lodgepole stands as a result of natural thinning, ortality caused by mountain pine beetle outbreaks and warf mistletoe infestations, and deadfall from previous res. Suppressed understories of subalpine fir and spruce eate fuel ladders from dead surface fuels to the overory. Eventually a chance ignition leads to a standplacement fire. Soils may become unstable following ch a fire especially on the steep slopes of the Idaho tholith.

Pinegrass often persists under near-climax conditions in wer elevation stands. Following fire, it can increase pidly from rhizomes and develop a dense sod that imedes establishment of other species, including trees teele and others 1983).

The Lodgepole Pine Fire Cycle—Brown (1975) summarized the lodgepole pine fire cycle and the many interrelated factors that influence it (fig. 26). His discussion of fire cycles and community dynamics in lodgepole pine forests is an important source of information on the role of fire in lodgepole pine forests. Brown also discussed the different effects of fires of varying severity on lodgepole pine forests. The critical role of fuel and duff moisture in determining fire severity and, consequently, fire effects is emphasized.

Fire and Dwarf Mistletoe—Infection by dwarf mistletoe, as noted earlier, usually enhances the flammability of lodgepole pine, thereby increasing the risk of severe wildfire and subsequent stand replacement. Such fires maintain lodgepole pine on the burned site and, in turn, assure that mistletoe seed sources are not eliminated. This can be an especially important role of fire in seral lodgepole pine stands growing on subalpine fir habitat types because succession toward nonsusceptible climax tree species is interrupted. In the unlikely event that no infected lodgepole pine remain adjacent to a burned area, the fire-regenerated stand could remain free of dwarf mistletoe.

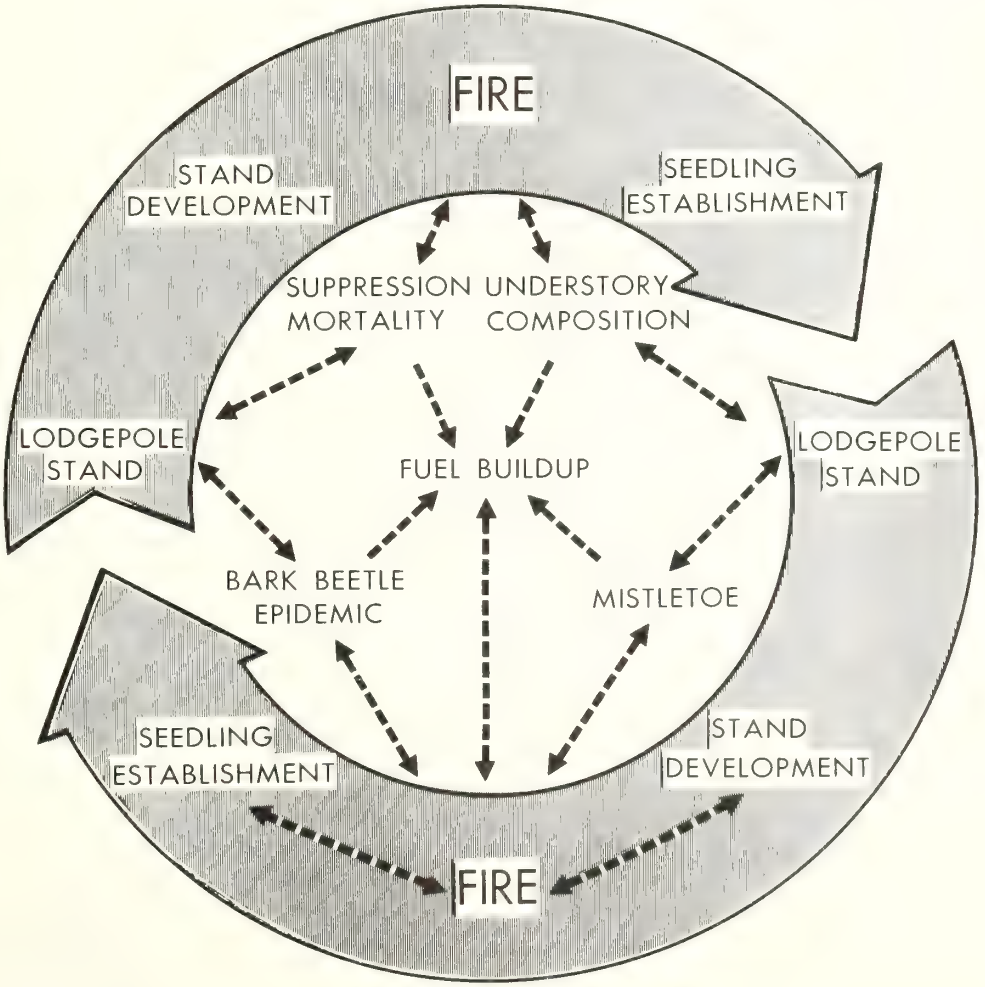


Figure 26—Lodgepole pine fire cycle showing interrelationships among influences (Brown 1975).

More likely, however, the spread of mistletoe from adjacent unburned mature stands into reproduction on the burned area would be relatively slow. Hawksworth (1958) reported an average spread rate of 1 to 2 feet (0.3 to 0.6 m) per year. Taylor (1969) found that infection in regenerated lodgepole pine burns in Yellowstone National Park was directly correlated with time since burn—only 1 percent of the lodgepole pines in the new stand were infected after 57 years; 10 percent after 111 years; and 36 percent after about 300 years. In situations where less-than-severe fires occur, surviving mistletoe-infected residual lodgepole pines will quickly infect young trees as soon as they are tall enough to remain at least partially uncovered by winter snows.

Fire and the Mountain Pine Beetle—The interactions of fire and mountain pine beetle are inextricable in most lodgepole pine forests. The following excerpt from Amman (1977) describes this interrelationship:

> ROLE OF MOUNTAIN PINE BEETLE WHERE LODGEPOLE PINE IS SERAL
>
> Absence of fire: Lodgepole pine stands depleted by the beetle and not subjected to fire are eventually succeeded by the more shade-tolerant species consisting primarily of Douglas-fir at the lower elevations and subalpine fir and Engelmann spruce at the higher elevations throughout most of the Rocky Mountains. Starting with a stand generated by fire, lodgepole pine grows at a rapid rate and occupies the dominant position in the stand. Fir and spruce seedlings also established in the stand grow more slowly than lodgepole pine.
>
> With each infestation, the beetle kills most of the large, dominant lodgepole pines. After the infestation, both residual lodgepole pine and the shade-tolerant species increase their growth. When the lodgepole pines are of adequate size and phloem thickness, another beetle infestation occurs. This cycle is repeated at 20 to 40 year intervals depending upon growth of the trees, until lodgepole pine is eliminated from the stand.
>
> The role played by the mountain pine beetle in stands where lodgepole pine is seral is to periodically remove the large, dominant pines. This provides growing space for subalpine fir and Douglas-fir, thus hastening succession by these species. The continued presence of the beetle in these mixed-species stands is as dependent upon fire as that of lodgepole pine. Without it both are eliminated.
>
> Presence of fire: Where lodgepole pine is seral, forests are perpetuated through the effects of periodic fires (Tackle 1964). Fires tend to eliminate competitive tree species such as Douglas-fir, the true firs, and spruces. Following fire, lodgepole pine seedlings may be abundant. If serotinous cones are present, they will open because of the intense heat and release their seed (Clements 1910, Lotan 1975).
>
> Large accumulations of dead material caused by periodic beetle infestations result in very hot fires when they do occur (Brown 1975). Hot fires of this nature eliminate Douglas-fir, which otherwi is more resistant to fire damage than lodgepole pine. The dominant shade-tolerant species are eliminated, resulting in a return to a pure lodgepole pine forest. On the other hand, light surfac fires would not be adequate to kill large, thick-barked Douglas-fir and return lodgepole pine to dominant position in the stand.
>
> Following regeneration of lodgepole pine after fire, the mountain pine beetle-lodgepole interactions would be similar to those described in the absence of fire. A fire may interrupt the sere at any time, reverting the stand back to pure lodgepole pine. However, once succession is complete, lodgepole pine seed will no longer be available t seed the burned areas except along edges where the spruce-fir climax joins persistent or climax lodgepole pine.
>
> ROLE OF MOUNTAIN PINE BEETLE WHER LODGEPOLE PINE IS PERSISTENT OR CLIMAX
>
> Lodgepole pine is persistent over large acreage and because of the number of shade-tolerant individuals of other species found in such persisten stands, the successional status is unclear (Pfister and Daubenmire 1975). In any case, lodgepole pin persists long enough for a number of beetle infestations to occur. In such cases and when lodgepol pine is climax because of climatic or soil conditions, the forest consists of trees of different size and ages ranging from seedlings to a few overmature individuals. In these forests, the beetle infests and kills most of the lodgepole pines as they reach larger sizes. Openings created in the stand as a result of the larger trees being killed, are seeded by lodgepole pine. The cycle is then repeated as other lodgepole pines reach sizes and phloem thicknesses conducive to increases in beetle populations.
>
> The result is two- or three-story stands consisting of trees of different ages and sizes. A mosaic of small clumps of different ages and sizes may occur. The overall effect is likely to be more chronic infestations by the beetle because of the more constant source of food. Beetle infestations in such forests may result in death of fewer trees per hectare during each infestation than would occur in even aged stands developed after fires and in those where lodgepole pine is seral.
>
> Fires in persistent and climax lodgepole pine forests should not be as hot as those where large epidemics of beetles have occurred. Smaller, more continuous deposits of fuel are available on the forest floor. The lighter beetle infestations, and thus lighter accumulations of fuel, would result in fires that would eliminate some of the trees but probably would not cause total regeneration of the stand. This would be beneficial to the beetle because a more continuous supply of food would

be maintained. Where large accumulations of fuel occur after large beetle epidemics, fire would completely eliminate the beetles' food supply from vast acreages for many years while the entire stand of trees grow from seedlings to sizes conducive to beetle infestation.

The mountain pine beetle's evolutionary strategies have been successful. It has exploited a niche that no other bark beetle has been able to exploit, that of harvesting lodgepole pine trees as they reach or slightly before they reach maturity. Such trees are at their peak as food for the beetle. Harvesting at this time in the age of the stand maintains the vigor of the stand, and keeps the stand at maximum productivity.

orest Succession

The theoretical climax forest on Fire Group Seven sites aries according to habitat type as shown in figure 27 ubsequent numbers in this section refer to fig. 27). Ex-pt for stands belonging to the PICO c.t.'s and the ICO/FEID h.t., however, fire usually interrupts succession ort of the climax condition.

Following a stand-destroying fire an herb/shrub stage dominates the site. Because most trees have open cones, seedlings establish over a period of several years. A fire in the herb/shrub stage (No. 1) will, however, extend its period of dominance. A fire during the seedling/sapling stage also returns the site to herbs and shrubs (No. 2). The likelihood of a fire at this stage is not great on most Group Seven sites.

The lack of fuels in most pole-stage stands renders fire unlikely, but should fire occur, its effects will depend on fire severity. A cool fire (No. 3) thins the stand and prepares a seedbed for lodgepole regeneration. A severe fire (No. 4) will destroy the stand; however, a new stand of lodgepole pine will generally recur. The effect of fire in a mature lodgepole forest is essentially the same as in the pole forest. A cool fire thins the stand and a severe fire recycles the stand (Nos. 5 and 6). The probability of a severe stand-destroying fire greatly increases as a previously unburned mature forest starts to break up and an understory of climax species develops. At this stage, a thinning fire (No. 7) is unlikely; if the stand is dry enough to burn it will probably burn severely (No. 8) because of hazardous fuel conditions.

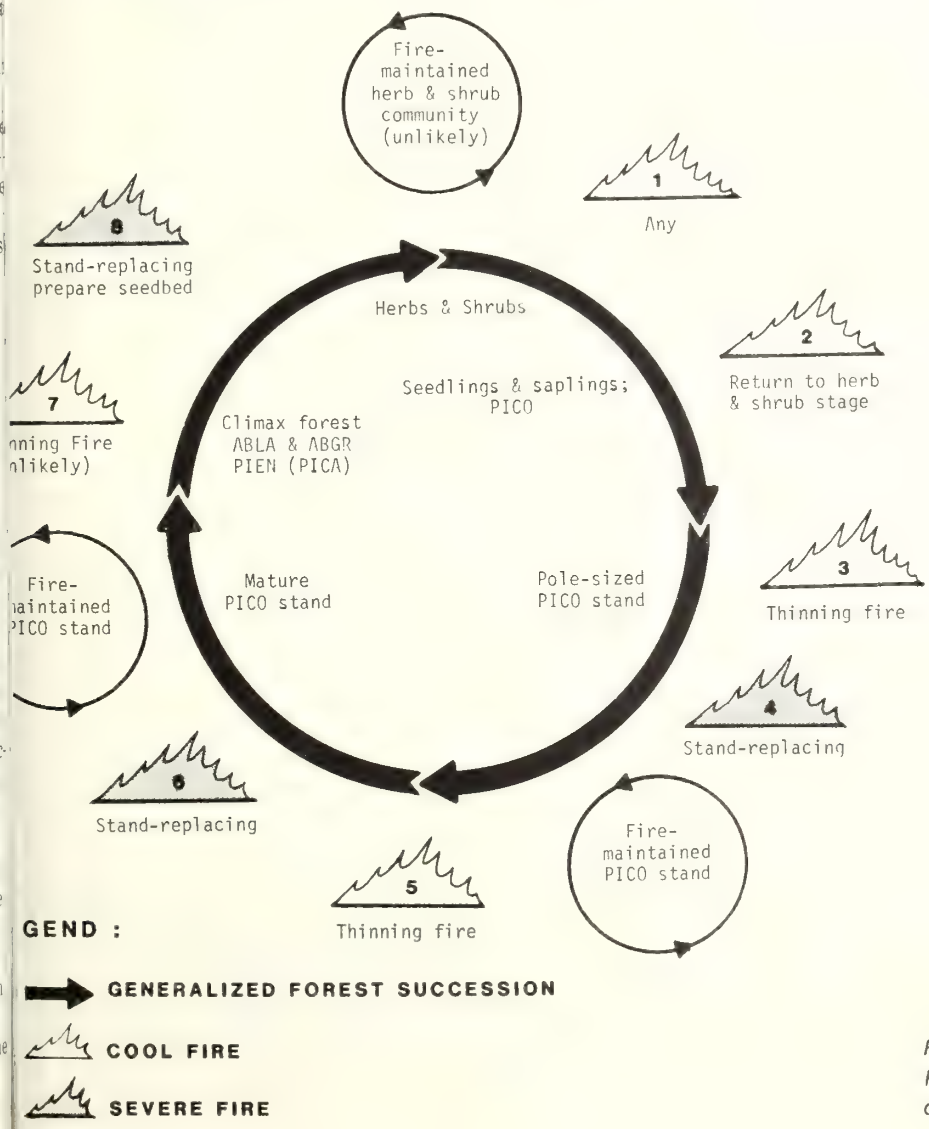

Fire-
maintained
herb & shrub
community
(unlikely)
1
Any
8
Stand-replacing
prepare seedbed
Herbs & Shrubs
2
Return to herb
& shrub stage
Seedlings & saplings;
PICO
Climax forest
ABLA & ABGR
PIEN (PICA)
7
nning Fire
nlikely)
3
Thinning fire
Fire-
aintained
PICO stand
Mature
PICO stand
Pole-sized
PICO stand
4
Stand-replacing
6
Stand-replacing
Fire-
maintained
PICO stand
5
Thinning fire
GEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 27—Generalized forest succession in Fire Group Seven: cool habitat types usually dominated by lodgepole pine.

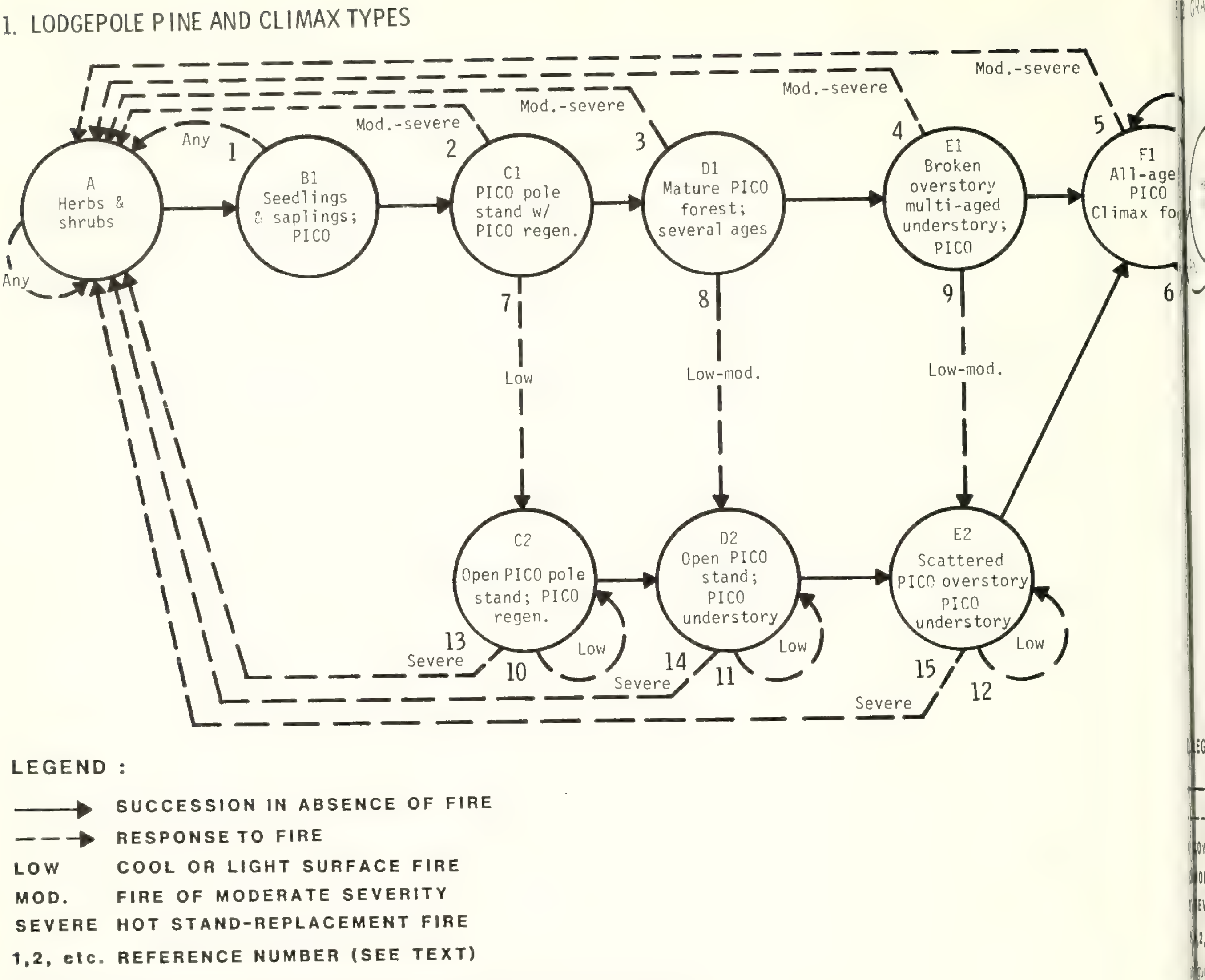

1. LODGEPOLE PINE AND CLIMAX TYPES
A Herbs & shrubs
B1 Seedlings & saplings; PICO
C1 PICO pole stand w/ PICO regen.
D1 Mature PICO forest; several ages
E1 Broken overstory multi-aged understory; PICO
F1 All-age PICO Climax fo
C2 Open PICO pole stand; PICO regen.
D2 Open PICO stand; PICO understory
E2 Scattered PICO overstory PICO understory
Any
Any
Mod.-severe
Mod.-severe
Mod.-severe
Mod.-severe
Low
Low-mod.
Low-mod.
Low
Low
Low
Severe
Severe
Severe
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
LEGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 28—Hypothetical fire-related successional pathways for Fire Group Seven.

Hypothetical successional pathways for Fire Group Seven stands are represented in figure 28.

Arno and others (1985) show the sequence of seral community types developing after stand-destroying wildfire and also for clearcutting with broadcast burning, mechanical scarification, or no followup treatment within the ABAL/XETE h.t. in western Montana.

Fire Management Considerations

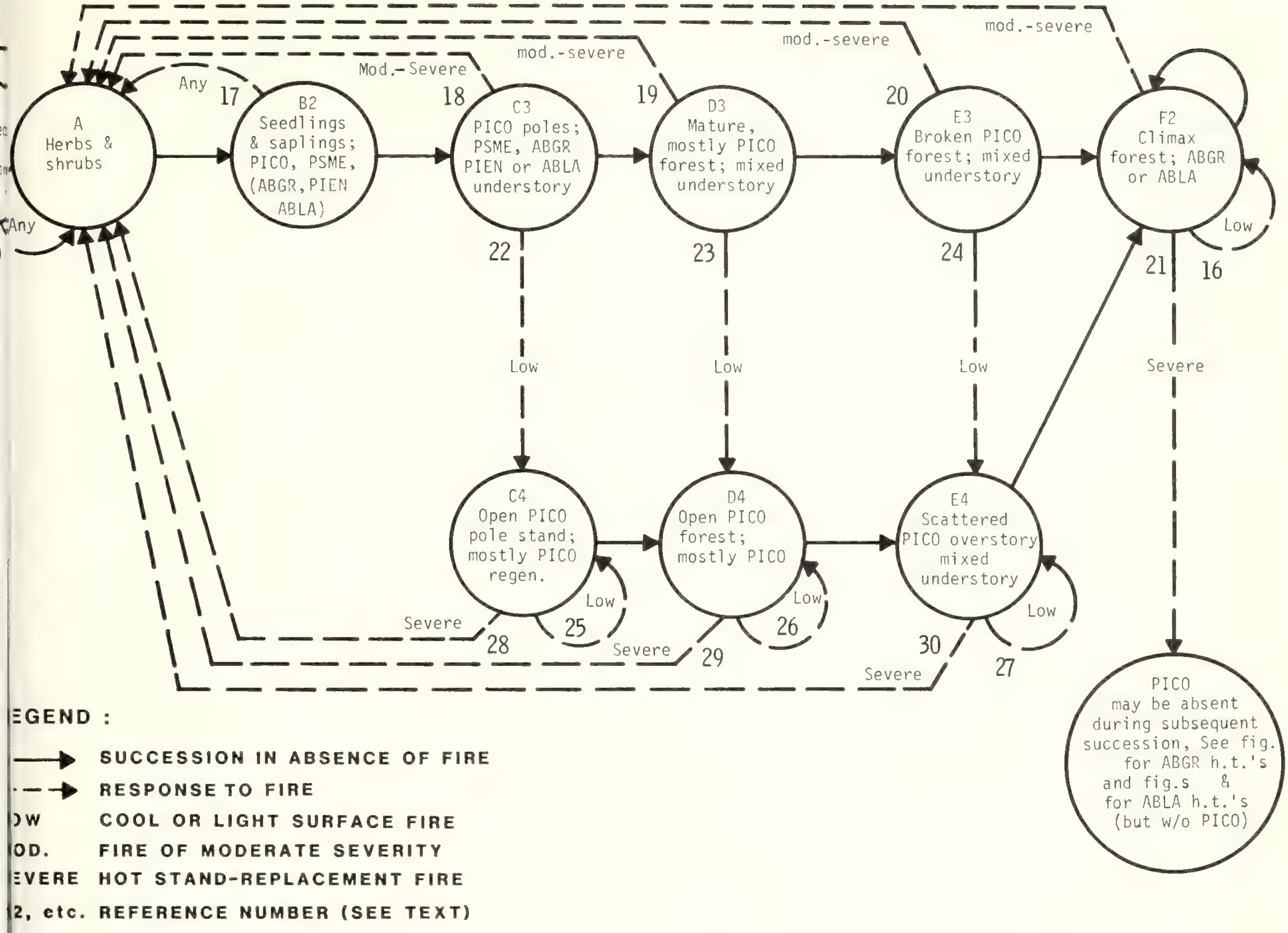
A primary fire management consideration in the Fire Group Seven habitat types is protection of high-hazard stands from unwanted fire during extended periods of drought and during severe fire weather conditions. Fires at such time often crown and result in complete stand mortality if the lodgepole stand is ready physiognomically to burn (Despain and Sellers 1977). Of course, in some management situations, this may be an acceptable result.

Opportunities for use of understory fire are limited in natural stands because of the low fire resistance of lodgepole pine, spruce, and subalpine fir. The other side of this problem is that during "safe" fire weather, it is often d ficult to sustain a fire in Group Seven stands. Low-to-medium severity surface fires, however, do occur. Thus, there may be opportunities to use prescribed fires to accomplish specific management objectives.

The primary use of prescribed fire in this group has been and undoubtedly will continue to be for hazard re tion and site preparation in conjunction with tree harve ing and subsequent regeneration. Broadcast burning an pile and windrow burning have been the most often use methods of accomplishing these tasks. Successful broad slash burning usually yields increased forage productior for big game. Slash disposal of any kind aids big game movement.

Prescribed fire can be an effective tool for controlling dwarf mistletoe in lodgepole pine stands. Alexander anc Hawksworth (1975) suggest two purposes for use of fire for mistletoe control: (1) to eliminate infected residual trees in logged-over areas, and (2) to destroy heavily infested, unproductive stands so that they can be replacec with young healthy stands.

GRAND FIR AND SUBALPINE FIR CLIMAX TYPES


A
Herbs & shrubs
B2
Seedlings & saplings; PICO, PSME, (ABGR, PIEN ABLA)
C3
PICO poles; PSME, ABGR PIEN or ABLA understory
D3
Mature, mostly PICO forest; mixed understory
E3
Broken PICO forest; mixed understory
F2
Climax forest; ABGR or ABLA
C4
Open PICO pole stand; mostly PICO regen.
D4
Open PICO forest; mostly PICO
E4
Scattered PICO overstory mixed understory
PICO may be absent during subsequent succession, See fig. for ABGR h.t.'s and fig.s & for ABLA h.t.'s (but w/o PICO)
Any
17
Mod.-Severe
18
mod.-severe
19
mod.-severe
20
mod.-severe
Any
22
Low
23
Low
24
Low
21
Severe
16
Low
25
Low
26
Low
27
Low
Severe
28
Severe
29
Severe
30
EGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
OW COOL OR LIGHT SURFACE FIRE
OD. FIRE OF MODERATE SEVERITY
EVERE HOT STAND-REPLACEMENT FIRE
2, etc. REFERENCE NUMBER (SEE TEXT)

ure 28 (Con.)

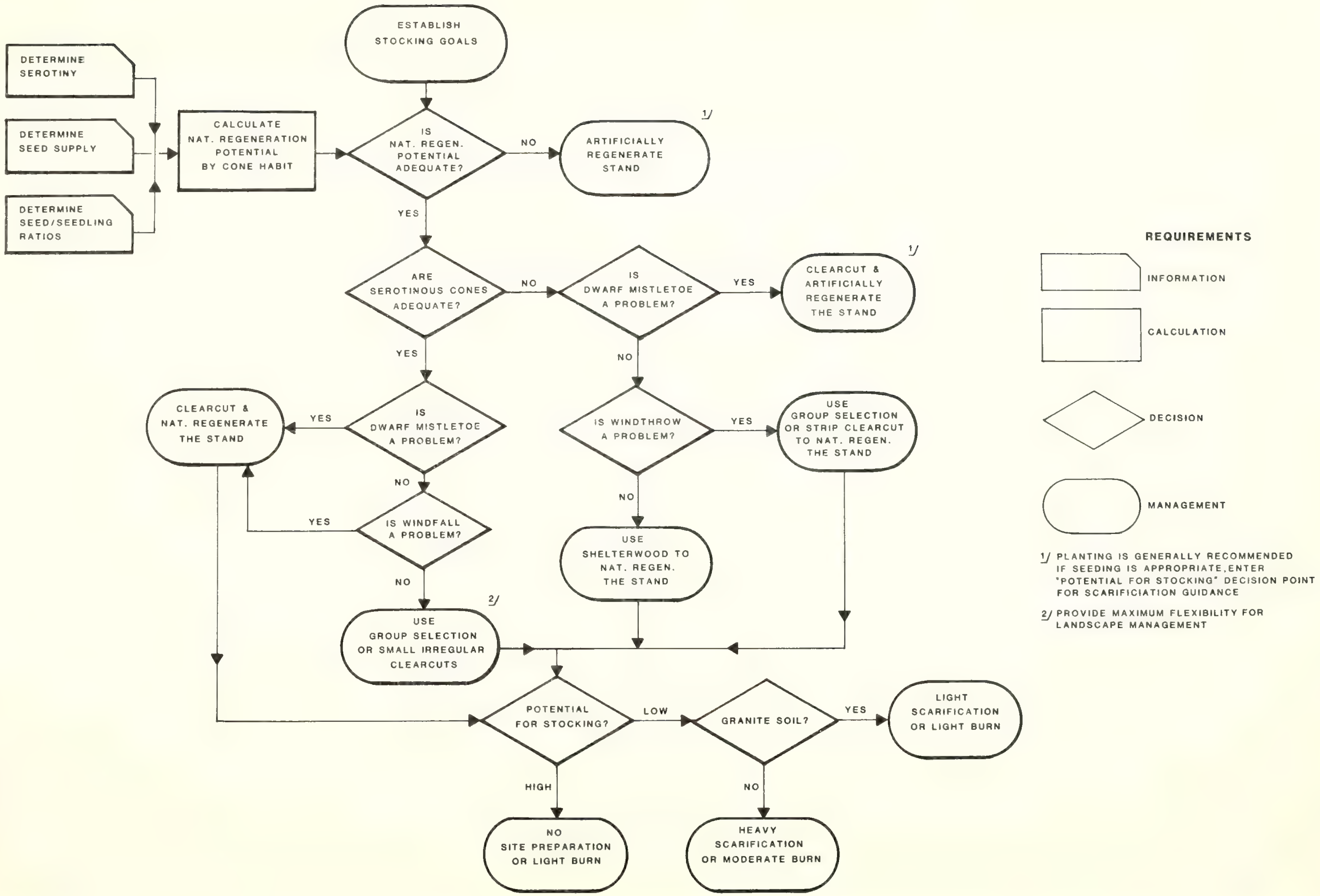

DETERMINE SEROTINY
DETERMINE SEED SUPPLY
DETERMINE SEED/SEEDLING RATIOS
CALCULATE NAT. REGENERATION POTENTIAL BY CONE HABIT
ESTABLISH STOCKING GOALS
IS NAT. REGEN. POTENTIAL ADEQUATE?
NO
ARTIFICIALLY REGENERATE STAND 1/
YES
ARE SEROTINOUS CONES ADEQUATE?
NO
IS DWARF MISTLETOE A PROBLEM?
YES
CLEARCUT & ARTIFICIALLY REGENERATE THE STAND 1/
NO
IS WINDTHROW A PROBLEM?
YES
USE GROUP SELECTION OR STRIP CLEARCUT TO NAT. REGEN. THE STAND
NO
USE SHELTERWOOD TO NAT. REGEN. THE STAND
YES
IS DWARF MISTLETOE A PROBLEM?
YES
CLEARCUT & NAT. REGENERATE THE STAND
NO
IS WINDFALL A PROBLEM?
YES
NO
USE GROUP SELECTION OR SMALL IRREGULAR CLEARCUTS 2/
POTENTIAL FOR STOCKING?
LOW
GRANITE SOIL?
YES
LIGHT SCARIFICATION OR LIGHT BURN
NO
HEAVY SCARIFICATION OR MODERATE BURN
HIGH
NO SITE PREPARATION OR LIGHT BURN
REQUIREMENTS
INFORMATION
CALCULATION
DECISION
MANAGEMENT
1/ PLANTING IS GENERALLY RECOMMENDED IF SEEDING IS APPROPRIATE, ENTER "POTENTIAL FOR STOCKING" DECISION POINT FOR SCARIFICIATION GUIDANCE
2/ PROVIDE MAXIMUM FLEXIBILITY FOR LANDSCAPE MANAGEMENT

Figure 29—The decision chain for lodgepole pine regeneration (Lotan and Perry 1983).

The various considerations that determine the appropri-
: use of fire for site preparation and regeneration of
gepole pine forests have been summarized by Lotan and
rry (1983) in figure 29.

\s indicated earlier, the primary concern in the fire
nagement of many lodgepole pine forests is the preven-
n of stand-destroying fires over large areas. Timber
vest for a variety of products and subsequent slash
posal are the primary techniques to meet this objective
en economic considerations are favorable. Harvest
edules should be developed and implemented to create
-class mosaics of lodgepole pine. This minimizes the
al extent of stand-destroying fires. Silvicultural prac-
s designed to harvest trees before they become suscep-
le to mountain pine beetle attack (Cole and Amman
30) can greatly reduce the threat of severe fires in
ond-growth stands of lodgepole pine. The use of
gepole pine for house logs, firewood, poles, posts, wood
ps, and sawlogs may provide opportunities for fuel
nagement-related harvesting.

n some wilderness areas, periodic crown fires play a
al role in natural development of lodgepole pine eco-
tems, and their use should be considered when consis-
t with the need to protect human life, property, and
ource values outside wilderness. A case for fire use in
gepole pine stands is presented by Fellin (1980):

> In many areas where natural fires have been suppressed, forest residues resulting from mountain pine beetle epidemics accumulate until hot fires occur. According to Cole (1978), "such fires are normally more destructive than ones that would have otherwise occurred if fires had not been suppressed, and they tend to perpetuate future extremes in the mountain pine beetle/lodgepole pine/fir interactions." Several opinions have been expressed that the bark beetle epidemics now rampant in the Rockies and Intermountain West may be a product of fire exclusion (Schwennesen 1979). In Glacier National Park, the mountain pine beetle epidemic took such a strong hold because fire suppression programs were so successful and trees that ordinarily might have been burned are now mature and ripe for the beetles (Kuglin 1980).
>
> Cole (1978) suggests that a deliberate program of fire management and prescribed fire can be instituted to moderate the mountain pine beetle-lodgepole pine-fire interaction cycle. His premise is that both wildfire and prescribed fire management plans can be developed to use fire to "create a mosaic of regenerated stands within extensive areas of timber that have developed." D. Cole (1978) believes that prescribed fires can create these ecosystem mosaics more effectively than wildfires. With the recent change from fire control to fire management, managed wildfires will be, in fact, prescribed fires.

Guidelines have been developed by McGregor and Cole (1985) to assist forest managers in integrating pest management techniques for the mountain pine beetle with other resource considerations in the process of planning and executing balanced resource management of lodgepole pine forests. The guidelines present visual and classification criteria and methods for recognizing and summarizing occurrence and susceptibility status of lodgepole pine stands according to habitat types and successional roles and important resource considerations associated with them. McGregor and Cole (1985) review appropriate silvicultural systems and practices, including use of fire, for commercial and noncommercial forest land designations, including parks, wilderness, and other reserved areas.

FIRE GROUP EIGHT: DRY, LOWER SUBALPINE HABITAT TYPES

ADP code	**Habitat type-phase**	**Physiographic sections**
	(Steele and others 1981)	(Steele and others 1981)
645	*Abies lasiocarpa/Acer glabrum* h.t. (ABLA/ACGL), subalpine fir/mountain maple	Southern Batholith
661	*Abies lasiocarpa/Linnaea borealis* h.t. - *Linnaea borealis* phase (ABLA/LIBO-LIBO), subalpine fir/twinflower - twinflower phase	Southern Batholith, Salmon Uplands, and Open Northern Rockies
723	*Abies lasiocarpa/Vaccinium globulare* h.t. - *Vaccinium globulare* phase (ABLA/VAGL-VAGL), subalpine fir/blue huckleberry - blue huckleberry phase	Southern Batholith and Salmon Uplands
705	*Abies lasiocarpa/Spiraea betulifolia* h.t. (ABLA/SPBE), subalpine fir/white spirea	Southern Batholith and Challis
745	*Abies lasiocarpa/Juniperus communis* h.t. (ABLA/JUCO), subalpine fir/common juniper	Southern Batholith and Open Northern Rockies
780	*Abies lasiocarpa/Arnica cordifolia* h.t. (ABLA/ARCO), subalpine fir/heartleaf arnica	Southern Batholith, Challis, and Open Northern Rockies

Figure 29 The decision chain for lodgepole pine regeneration (Lotan and Perry 1983)

Vegetation

Fire Group Eight is a collection of warm, lower subalpine habitat types that are generally dominated by seral Douglas-fir although subalpine fir is the indicated climax. A mixture of Douglas-fir and lodgepole pine may dominate seral stands belonging to the ABLA/LIBO, ABLA/SPBE, ABLA/VAGL, ABLA/JUCO, and ABLA/ARCO h.t.'s. Englemann spruce may dominate late seral stands within the ABLA/VAGL-VAGL, ABLA/LIBO, and ABLA/ARCO h.t.'s (fig. 30).

Common shrubs are white spirea, common juniper, russet buffaloberry, mountain snowberry, blue huckleberry, Utah honeysuckle, Sitka alder, mountain maple, and mountain ash. Columbia clematis occurs on these sites along with herbs such as heartleaf arnica, sidebells pyrola, twinflower, elk sedge, pinegrass, western meadowrue, and Wilcox's penstemon. Mosses are notable in some stands within the drier ABLA/JUCO and ABLA/ARCO h.t.'s.

Forest Fuels

Downed, dead, woody fuel loadings on lower subalpi habitat types in Montana and northern Idaho average between 20 and 25 tons/acre (5 and 6 kg/m^2) (Brown a See 1981); stands inventoried by Fischer (1981c) range between 1 and 80 tons/acre. As a general rule, the heaviest downed, dead, woody fuel loads on central Ida forests occur in lower subalpine stands of this Fire Gr

A large percentage of the fuel load is made up of material greater than 3 inches (7.62 cm) in diameter; 1 and 20-inch (25- and 50-cm) material is not uncommon. The large material is the result of downfall of dead ove story trees. The long fire-free intervals characteristic o this Fire Group allow these large materials to accumul for many decades. Because of the long time spans involved, much of the material is rotten.

Live and standing dead fuels can contribute significa to overall fire hazard during dry conditions. Dense spru and fir understory trees along with low-hanging, moss-covered live and dead branches of overstory trees form effective fuel ladders to the overstory tree crowns.

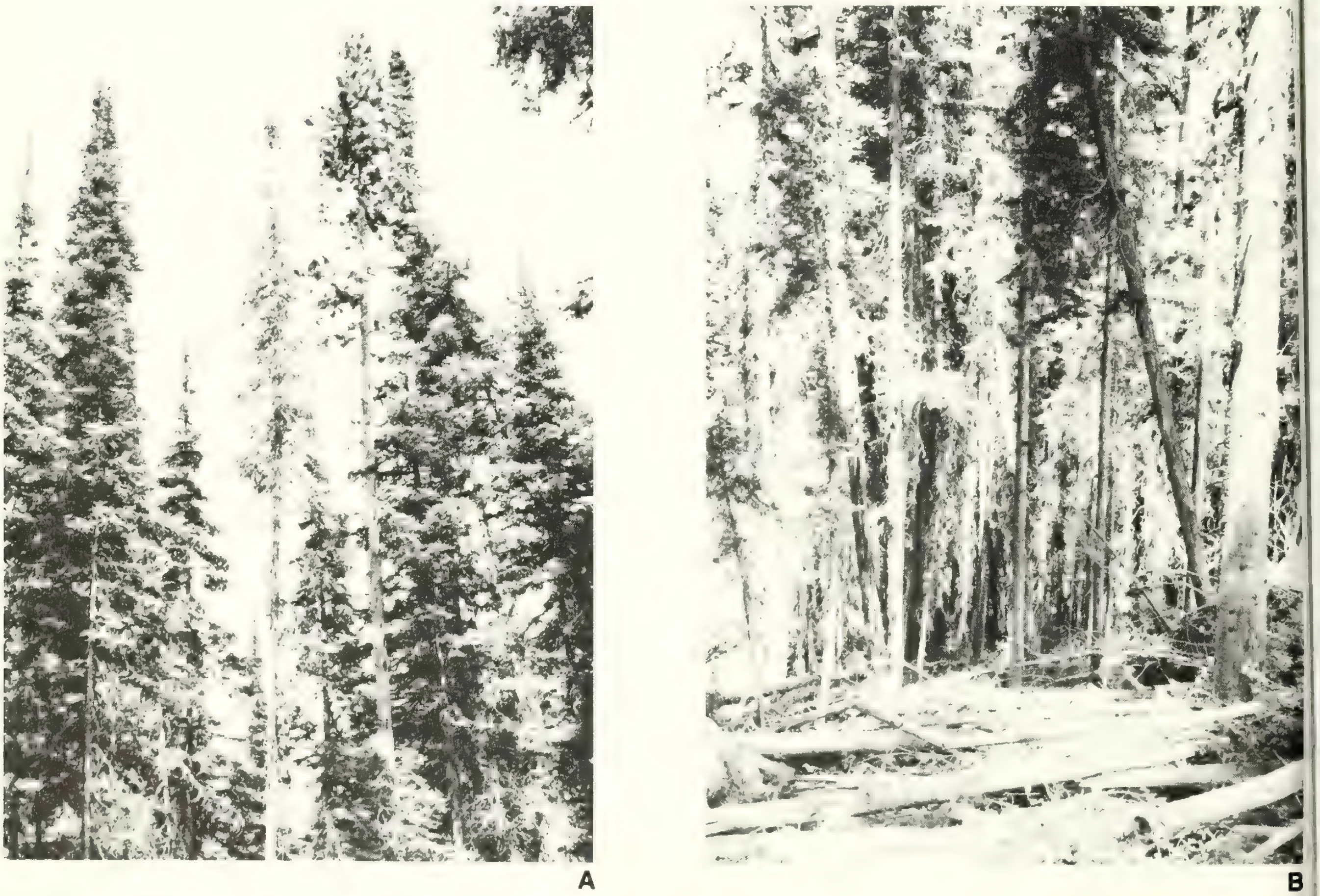


Figure 30—Two views of the same ABLA/LIBO h.t. near the Lick Creek Road, Salmon National Forest. (A) The stand is dominated by late seral Engelmann spruce and subalpine fir although a few seral lodgepole pines remain. (B) The forest floor shows characteristic fuel buildup associated with the breakup of the former lodgepole stand.

Relatively deep duff layers may form on forest floors. hen this duff layer becomes dry and burns it can cause nsiderable mortality by heating the shallow roots of ıbalpine fir and Engelmann spruce. Dry rotten logs on e forest floor are partially incorporated into the duff yer and will intensify this effect. The fuel loadings for e transition and spruce-fir classes listed in table 7 (Fire roup Seven) should be representative of similar stands in e group.

ole of Fire

Fire history information is generally lacking. Where ailable, fire history studies of subalpine forest mainly pply to lodgepole pine-dominated seral stands. Gabriel 976) indicates that some of the stands he studied in the b Marshall Wilderness are similar to stands in Fire roup Eight. One of Gabriel's stands contained fire- arred trees although the entire area did not burn each ne. In another stand, he found no sign of fire in the past 0 years. Other stands showed evidence of light fires durg the last 100 years.

Stand composition following a fire may be quite variable. w-to-moderate surface fires generally favor residual Douglas-fir over the thinner barked lodgepole pine. Severe fires favor lodgepole pine regeneration if serotinous cones are present in the prefire stand. Some large, thick-barked Douglas-fir trees often survive fires severe enough to kill all the lodgepole pine, thus ensuring its presence in future stands. Cones in tips of fire-killed Douglas-fir may provide viable seed. Any fire will set back invasion of the stand by spruce or subalpine fir, which eventually dominate the site in the absence of fire.

The theoretical climax forest is dominated by subalpine fir. This climax requires such a long fire-free period to develop that it is rarely found. A near-climax situation characterized by a dense understory of subalpine fir along with an overstory of this species accompanied by Douglas-fir and spruce is more common.

Forest Succession

A general pattern for forest succession in Fire Group Eight is shown in figure 31. (All numbers in the section refer to fig. 31.) The time required for seedlings to establish following a fire varies, depending upon site conditions, moisture, and seed source, including the presence or absence of serotinous-coned lodgepole pine. Following a

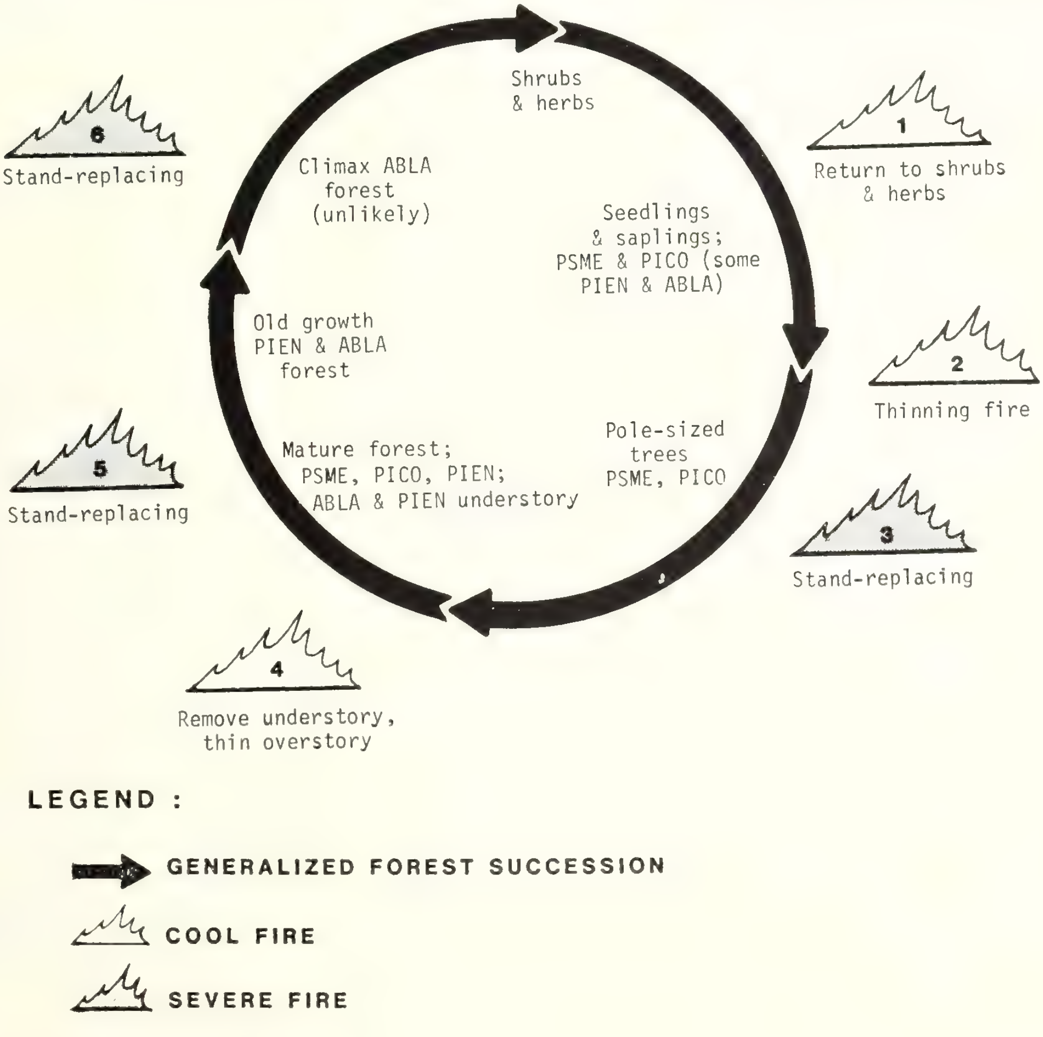
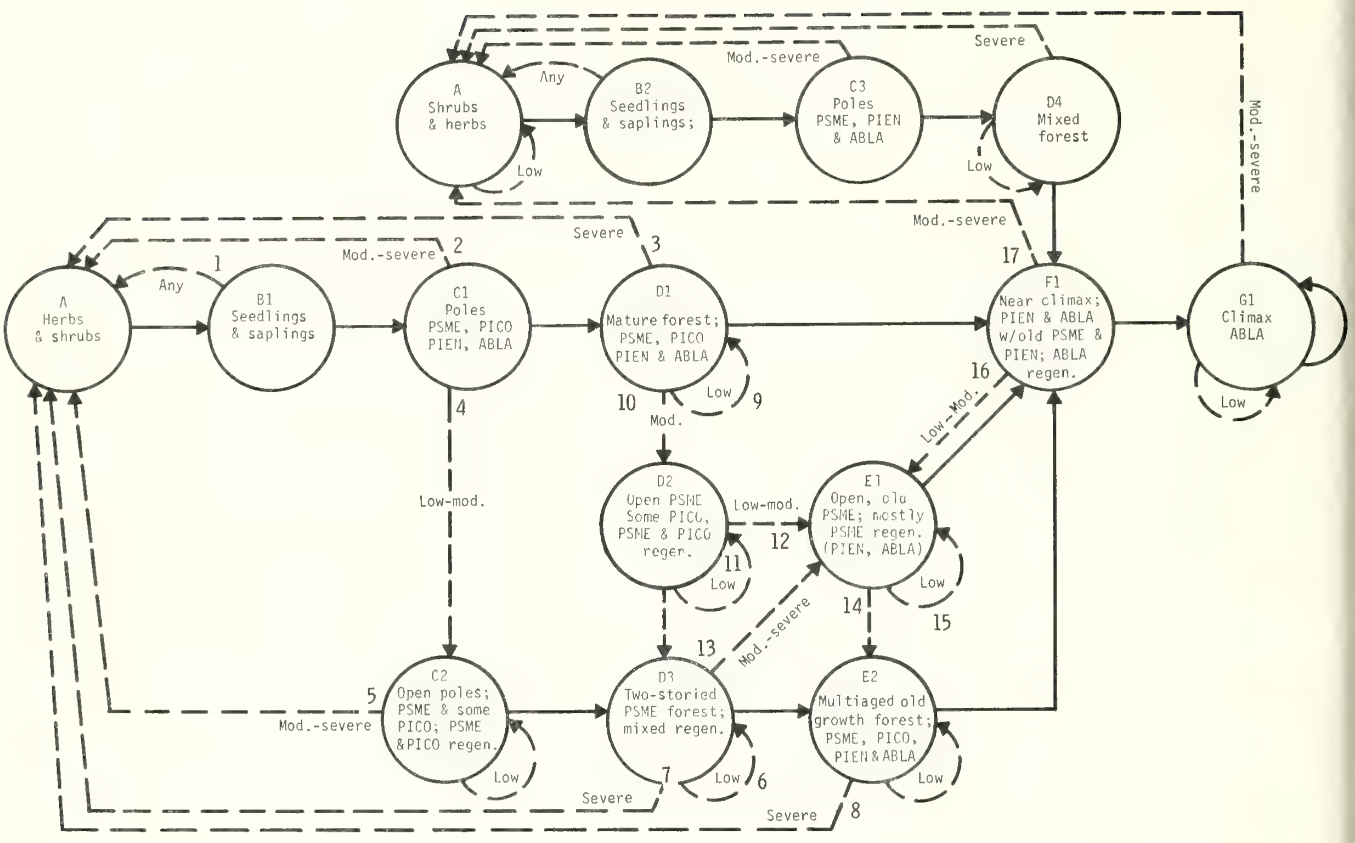

Shrubs & herbs
1
Return to shrubs & herbs
Seedlings & saplings; PSME & PICO (some PIEN & ABLA)
2
Thinning fire
Pole-sized trees PSME, PICO
3
Stand-replacing
Mature forest; PSME, PICO, PIEN; ABLA & PIEN understory
4
Remove understory, thin overstory
Old growth PIEN & ABLA forest
5
Stand-replacing
Climax ABLA forest (unlikely)
6
Stand-replacing
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 31—Generalized forest succession in Fire Group Eight: lower subalpine habitat types.

1. MIXED SPECIES SUCCESSION


A
Shrubs & herbs
Any
Low
B2
Seedlings & saplings;
C3
Poles
PSME, PIEN & ABLA
Mod.-severe
Severe
D4
Mixed forest
Low
Mod.-severe
Mod.-severe
17
A
Herbs & shrubs
Any
1
B1
Seedlings & saplings
Mod.-severe
2
C1
Poles
PSME, PICO PIEN, ABLA
Severe
3
D1
Mature forest; PSME, PICO PIEN & ABLA
Low
9
10
Mod.
F1
Near climax; PIEN & ABLA w/old PSME & PIEN; ABLA regen.
16
Low-Mod.
G1
Climax ABLA
Low
4
Low-mod.
D2
Open PSME Some PICO, PSME & PICO regen.
Low-mod.
12
11
Low
E1
Open, old PSME; mostly PSME regen. (PIEN, ABLA)
Low
14
15
13
Mod.-severe
5
Mod.-severe
C2
Open poles; PSME & some PICO; PSME & PICO regen.
Low
D3
Two-storied PSME forest; mixed regen.
Low
6
Severe
7
E2
Multiaged old growth forest; PSME, PICO, PIEN & ABLA
Low
Severe
8

2. SUCCESSION WITHOUT LODGEPOLE PINE AND SPRUCE (ABLA/ACGL h. t.)

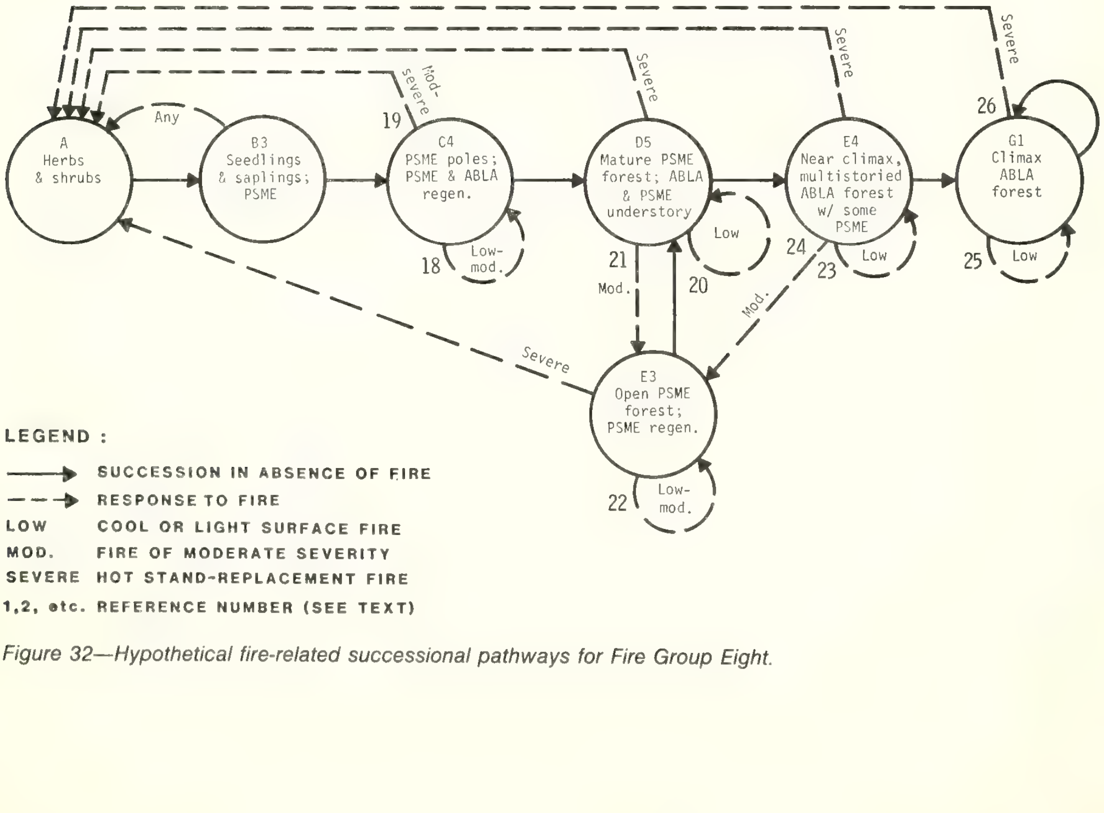

Severe
Severe
Severe
Mod-severe
19
26
A
Herbs & shrubs
Any
B3
Seedlings & saplings; PSME
C4
PSME poles; PSME & ABLA regen.
Low-mod.
18
D5
Mature PSME forest; ABLA & PSME understory
Low
21
Mod.
20
E4
Near climax, multistoried ABLA forest w/ some PSME
24
Low
23
Mod.
G1
Climax ABLA forest
25
Low
Severe
E3
Open PSME forest; PSME regen.
Low-mod.
22
LEGEND:
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 32—Hypothetical fire-related successional pathways for Fire Group Eight.

and-replacement fire (Nos. 3, 5, and 6) within the BLA/ACGR h.t., a tall shrub field can persist for ecades. Douglas-fir is generally the only seral conifer on ands belonging to the ABLA/ACGR h.t. Within other bitat types in this fire group, the seedlings and saplings n the site are generally a mixture of Douglas-fir and dgepole pine. Any fire in the seedling/sapling stage ould return the site to shrubs and herbs (No. 1).

Pole-size stands are usually mixtures of Douglas-fir and dgepole pine. A low-to-moderate fire can favor the more re-resistant Douglas-fir (No. 2). A severe fire (No. 3) uld favor lodgepole pine if cones in the prefire stand ere serotinous. If no fire occurs, a mature stand of ouglas-fir and lodgepole pine will develop. There may so be some spruce in the stand, and regeneration under e canopy is likely to be spruce and subalpine fir on many es. A surface fire would remove most of this fire-sceptible understory and overstory lodgepole pine, open- g the stand and favoring Douglas-fir (No. 4). Severe fire o. 5) would return the site to herbs and shrubs and ght again favor lodgepole pine if sufficient trees had rotinous cones. Periodic fire favors lodgepole pine on me sites. If fire continues to be absent, a climax balpine fir forest will develop.

The hypothetical successional pathway diagram for Fire oup Eight is shown in figure 32. Because both lodge- le pine and spruce are normally absent within the BLA/ACGL h.t., a separate pathway is shown for this bitat type.

The mixed species pathway generally applies to all bitat types except the ABLA/ACGL. Remember, wever, that spruce is lacking on stands belonging to the BLA/SPBE h.t.

re Management Considerations

ire protection is usually an important fire management c sideration during severe burning conditions especially o sites managed for timber production. At other times, fi may be of low-to-moderate severity and result in only m derate damage or no damage to overstory trees, d pite the relatively low resistance of many of the species p sent. Large, overstory Douglas-fir should easily survive fi s of low-to-moderate severity.

ire can be used to dispose of logging slash on harvest a as, but broadcast burning for site preparation is often h pered by high duff moisture and scarcity of acceptable b ning days during traditional spring and fall prescribed b ning periods. Summer burning has, consequently, b ome common in subalpine sites in some areas.

here timber production is not a management objective, o ortunities may exist for implementing fire management p scriptions that allow the use of naturally ignited fires. S h fires can create vegetational mosaics that provide a d rsity of wildlife habitat. Vegetational mosaics can also re ice the probability of widespread wildfire damage to so and watershed values.

FIRE GROUP NINE: WET OR MOIST, LOWER SUBALPINE HABITAT TYPES

ADP code	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
440	*Picea engelmannii/Galium triflorum* h.t. (PIEN/GATR), Engelmann spruce/ sweetscented bedstraw	Open Northern Rockies
490	*Picea engelmannii/Carex disperma* h.t. (PIEN/CADI), Engelmann spruce/soft-leaved sedge	Challis and Open Northern Rockies
410	*Picea engelmannii/Equisetum arvense* h.t. (PIEN/EQAR), Engelmann spruce/common horsetail	Challis and Open Northern Rockies
605	*Abies lasiocarpa/Caltha biflora* h.t. (ABLA/CABI), subalpine fir/marsh marigold	Southern Batholith
652	*Abies lasiocarpa/ Calamagrostis canadensis* h.t. - *Ligusticum canbyi* phase (ABLA/CACA-LICA), subalpine fir/bluejoint - Canby's ligusticum phase	Salmon Uplands and Southern Batholith
637	*Abies lasiocarpa/Streptopus amplexifolius* h.t. - *Ligusticum canbyi* phase (ABLA/STAM-LICA), subalpine fir/twisted stalk - Canby's ligusticum phase	Salmon Uplands
636	*Abies lasiocarpa/Streptopus amplexifolius* h.t. - *Streptopus amplexifolius* phase (ABLA/STAM-STAM), subalpine fir/twisted stalk - twisted stalk phase	Southern Batholith, Challis, and Open Northern Rockies
625	*Abies lasiocarpa/Clintonia uniflora* h.t. - *Menziesia ferruginea* phase (ABLA/CLUN-MEFE), subalpine fir/queencup beadlily - menziesia phase	Salmon Uplands and Southern Batholith
621	*Abies lasiocarpa/Clintonia uniflora* h.t. - *Clintonia uniflora* phase (ABLA/CLUN-CLUN), subalpine fir/queencup beadlily - queencup beadlily phase	Salmon Uplands and Southern Batholith
638	*Abies lasiocarpa/Coptis occidentalis* h.t. (ABLA/COOC), subalpine fir/western goldthread	Salmon Uplands

ADP code	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
671	*Abies lasiocarpa/Menziesia ferruginea* h.t. - *Menziesia ferruginea* phase (ABLA/MEFE-MEFE), subalpine fir/menziesia - menziesia phase	Salmon Uplands, Wallowa-Seven Devils, and Southern Batholith
672	*Abies lasiocarpa/Menziesia ferruginea* h.t. - *Luzula hitchcockii* phase (ABLA/MEFE-LUHI), subalpine fir/menziesia - smooth woodrush phase	Salmon Uplands

Vegetation

Englemann spruce is usually dominant either as a persistent seral species or, mainly in the Challis and Open Northern Rockies sections, as the climax species. Within the ABLA/CLUN h.t., Douglas-fir and lodgepole pine may be major seral species and lodgepole pine may precede Engelmann spruce as a major seral species within the ABLA/COOC h.t. Lodgepole pine and Douglas-fir occur as minor seral species or accidentals within other habitat types in this Fire Group. Western larch may be present in seral stands belonging to the ABLA/CLUN, ABLA/COOC, and ABLA/MEFE h.t.'s. Grand fir may be a coclimax species within ABLA/MEFE-MEFE and ABLA/CLUN-CLUN h.t.'s.

On many sites wet-site herbs and mosses dominate the undergrowth, while shrubs and herbs more characteristic of drier sites grow on hummocks or at the base of trees (Steele and others 1981). Seral stands may be dominate by wet-site herbs. On better drained sites the undergro is variable and shrubs may dominate early seral communities. Some characteristic undergrowth shrubs are prickly currant, blue huckleberry, menziesia, Labrador-t bearberry, honeysuckle, and grouse whortleberry. The r herb layer includes queencup beadlily, sweetscented bedstraw, red baneberry, arrowleaf groundsel, claspleaf twisted stalk, soft-leaved sedge, common horsetail, fireweed, sidebells pyrola, western meadowrue, brook saxifrage, marsh marigold, bluejoint, Canby's ligusticum Columbian monkshood, fivestamen miterwort, spreading sweet-root, bracted pedicularis, western goldthread, Piper's anenome, darkwoods violet, shooting star, beargrass, and heartleaf arnica.

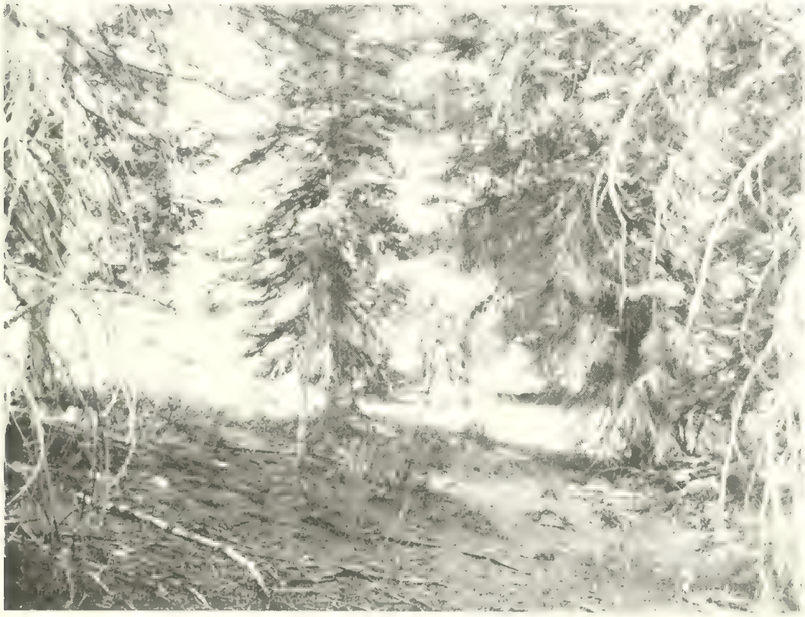


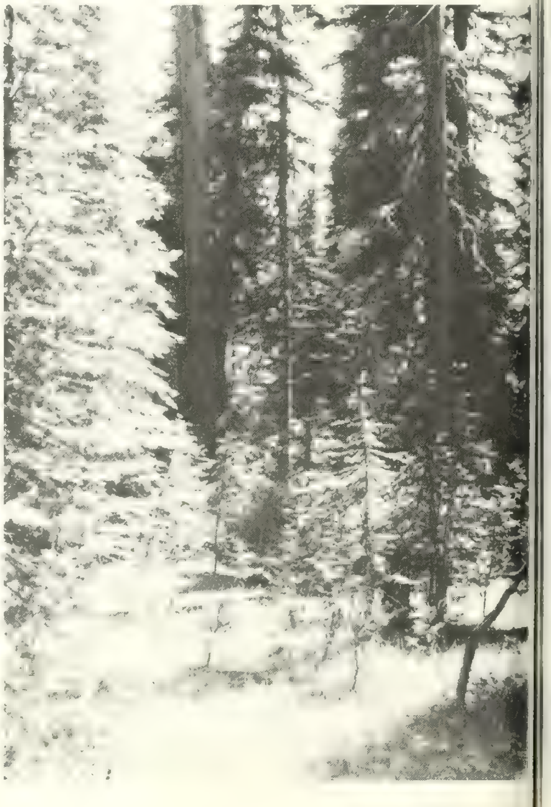
Figure 33—ABLA/CACA-LEGL h.t.'s occupying low benches along Cloochman Creek, Payette National Forest.

Forest Fuels

Fuel conditions are similar to those of Group Eight. Total downed, dead, woody fuel loads may average sligh heavier than in Group Eight because of the larger size tained by overstory spruce and the longer fire-free inter vals often experienced on these wet sites.

A large percentage of the downed woody fuel exceeds 3 inches (7.6 cm) in diameter (see table 7, Fire Group Eight). The combination of deep duff and large amount dead, rotten fuel can result in a severe surface fire duri unusually dry moisture conditions. When dense understories exist, such fires can easily spread to the tree crowns and destroy the stand (fig. 33). Even if a severe surface fire does not crown, there is a good chance the overstory spruce and subalpine fir will be killed by cambium heating.

A



Under normal moisture conditions for these sites, a lush undergrowth of shrubs and herbs usually serves as an effective barrier to rapid fire spread. These stands are probably more susceptible to damage from fire which sweeps in from adjoining areas than from fire that starts within the stand.

Role of Fire

Fire history is lacking for these moist, subalpine forest stands in central Idaho. Evidence from similar habitats in other Rocky Mountain areas suggests that fewer fires occur on these sites than on the drier upland subalpine sites. The mean fire-free intervals for sites within a ABLA/CLUN h.t. at Coram Experimental Forest in northwestern Montana were about 140 years (Sneck [Davis] 977). Fires at Coram were reported to be small, moderately severe surface fires that occasionally crowned, specially near ridgetops (Arno 1980). Romme and Knight 1981) found intervals of 300 to 400 years between fires in rainage bottoms compared to 300 years for drier upland sites of the Medicine Bow National Forest in southwestern Wyoming.

Steele and others (1981) found evidence of fire in spruce habitat types of central Idaho that suggests less frequent fires than on adjacent slopes. The characteristically wet undergrowths of Fire Group Nine stands do not normally support surface fires. Under severe burning conditions they are, however, susceptible to damage from wind-driven crown fires originating in adjacent stands.

Forest Succession

A general outline of forest succession for Fire Group Nine is shown in figure 34 (subsequent numbers in this section refer to fig. 34). Following a stand-replacing fire, herbs and shrubs will dominate until seedlings and saplings become well established. Within the ABLA/CACA-VACA h.t., aspen may be present in the immediate postfire vegetation if it was present in the prefire stand. Spruce generally dominates the initiating stand, with lodgepole pine, Douglas-fir, and western larch as minor seral species within some habitat types. Sometimes grand fir or subalpine fir are also present.

A fire during the seedling/sapling stage is unlikely, but if one did occur the area would return to the shrub/herb

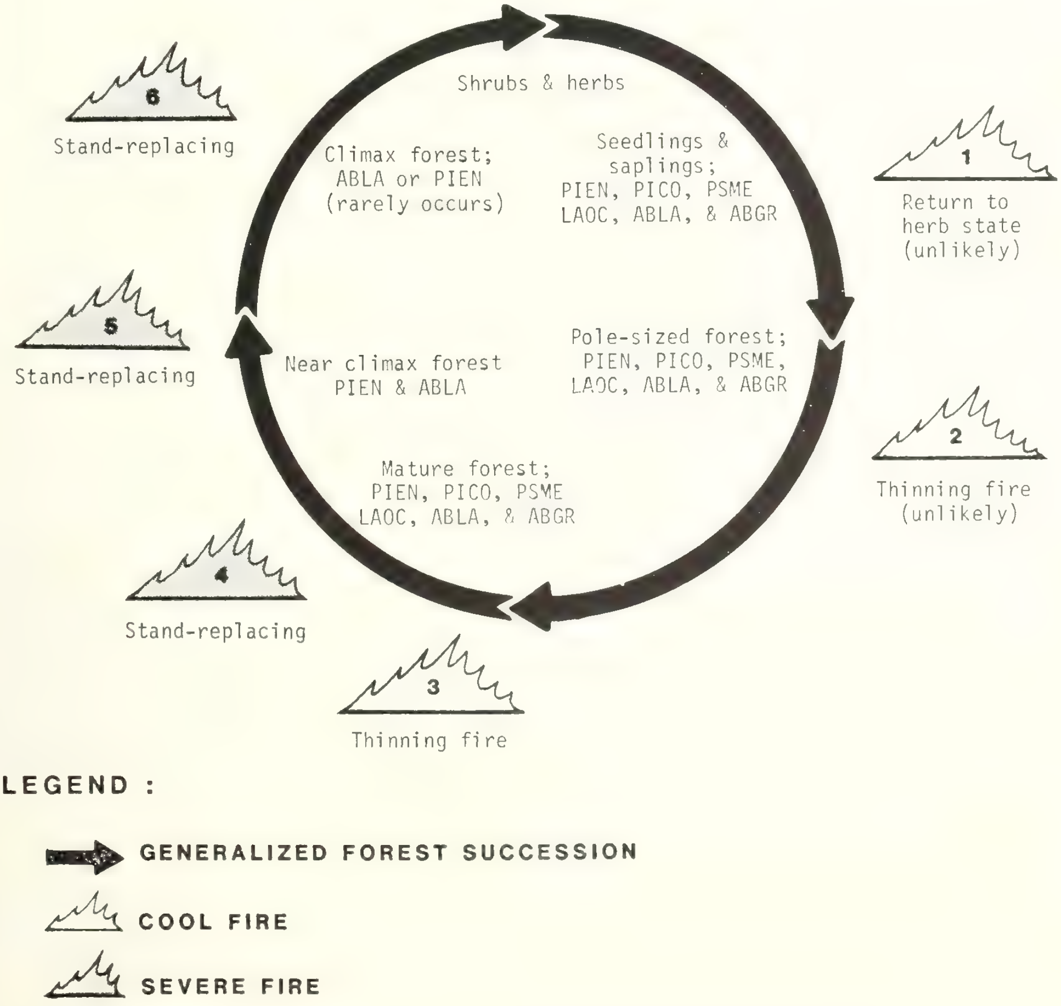

Shrubs & herbs
Seedlings & saplings; PIEN, PICO, PSME LAOC, ABLA, & ABGR
Pole-sized forest; PIEN, PICO, PSME, LAOC, ABLA, & ABGR
Mature forest; PIEN, PICO, PSME LAOC, ABLA, & ABGR
Near climax forest PIEN & ABLA
Climax forest; ABLA or PIEN (rarely occurs)
1
Return to herb state (unlikely)
2
Thinning fire (unlikely)
3
Thinning fire
4
Stand-replacing
5
Stand-replacing
6
Stand-replacing
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 34—Generalized forest succession in Fire Group Nine: very moist lower subalpine habitat types.

stage (No. 1). The moisture of the sites and lush undergrowth make fires unlikely during the pole stage as well. Any fire that did occur would probably be a cool surface fire that would thin the poles favoring the more resistant Douglas-fir, if present, and larch (No. 2). A cool fire in a mature stand would also thin the more susceptible stems and reduce accumulated surface fuels (No. 3). It is at this stage that stand replacement fires become a possibility (No. 4). In many stands in this Fire Group other disturbances such as spring flooding and windthrow help maintain the mature forest stage by creating openings and mineral soil for seral tree establishment. During the time required to achieve the near climax and climax situations, stand replacement fires (Nos. 5 and 6) are very likely. The theoretical climax rarely occurs.

The pattern of tree succession in Group Nine (fig. 35) is relatively simple. This simplicity is more a reflection of lack of knowledge than lack of vegetative complexity of Group Nine communities. Perhaps the most significant information gap has to do with the frequency of occurrence and related effects of cool to moderately severe fires on these moist sites. Figure 35 indicates a minimum impact for cool fire and does not include moderately severe fires. Intuitively, one might expect that fires of moderate severity do occur and thin out groups of trees rather than individual trees throughout the stand. If this in fact is the case, the effect of a moderately severe fire is the same as a severe fire, but on a small area within the stand.

The simplicity of this figure also reflects the assumption that Group Nine sites are generally either too moist to burn or, under conditions of extended summer drought, susceptible to wind-driven crown fire. In other words, either the whole thing burns, or it hardly burns at all.

Arno and others (1985) show the sequence of seral community types that develop after stand-destroying wildfire and after clearcutting with broadcast burning, mechanical scarification, and no follow-up treatment within the ABLA/MEFE h.t. in western Montana.

Fire Management Considerations

Fire protection is usually necessary in undisturbed stands during severe burning conditions. This is especiall true for areas where timber production is a management objective. At other times, fires may be of low to moderat severity and result in little or no damage to overstory trees (other than subalpine fir), despite the relatively low fire resistance of the species present. If slash is present, unacceptable tree mortality can result even under moderate burning conditions.

Broadcast burning is an effective method for reducing slash hazard and for preparing seedbeds in clearcuts, bu not in partial cuts. Timing of a burn is important. Group Nine sites are so cool and moist that opportunities for broadcast burning are limited. The moisture content of t duff must be low enough to allow the fire to bare miner soil over 20 percent or more of the area. Often, such favorable moisture conditions occur only during late summer.

Burning slash in large windrows or piles can create enough heat to alter the physical structure of the soil. Lower densities and slower growth of conifers on such sites can persist for 15 years or more (Vogl and Ryder 1969). Consequently, windrows should be narrow and pil should be small. Slash disposal plans should consider lea ing some large residues for nutrient cycling and to shad seedlings.

Additional guidelines for using fire for slash disposal site preparation in spruce-fir stands are provided by Ro and others (1970). This reference should be consulted along with local silvicultural guides before planning fire use in these habitats.

The often complex structure of subalpine forests refle their fire history. Their natural development has not, as general rule, been noticeably affected by past fire suppression policies (Habeck and Mutch 1973). Managemen objectives for these sites are often oriented toward non-

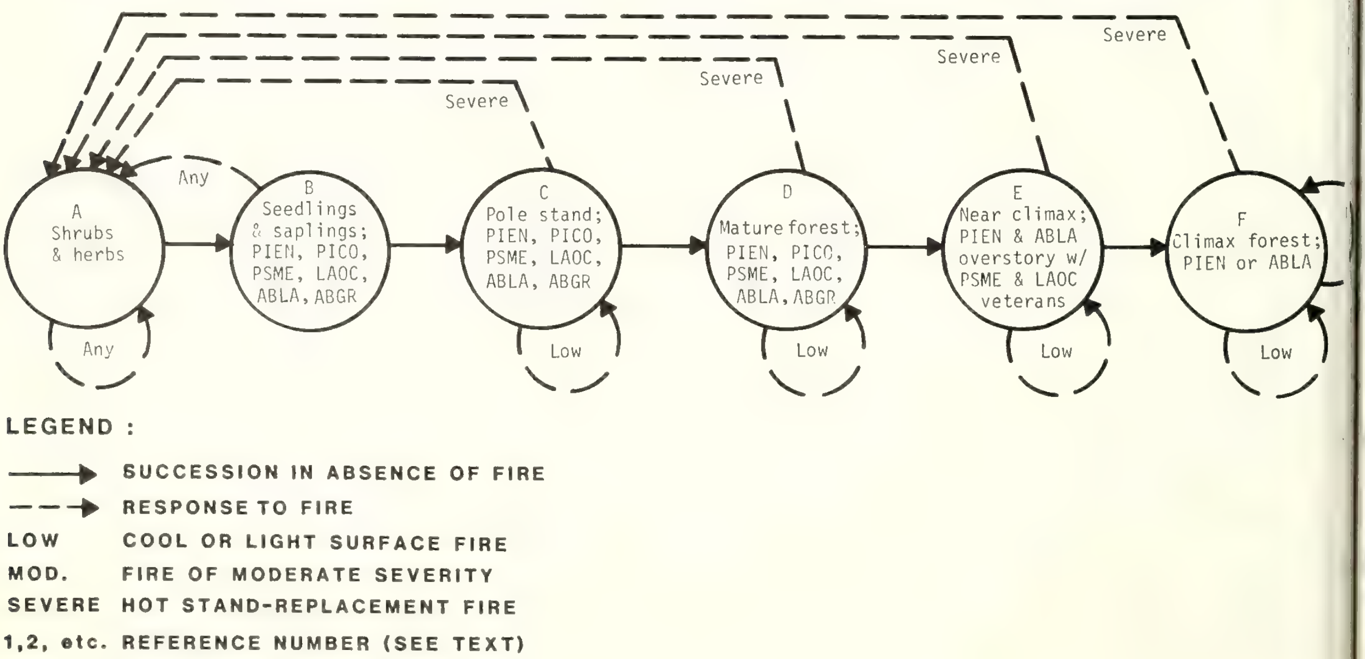

Severe
Severe
Severe
Severe
Any
A
Shrubs
& herbs
Any
B
Seedlings
& saplings;
PIEN, PICO,
PSME, LAOC,
ABLA, ABGR
C
Pole stand;
PIEN, PICO,
PSME, LAOC,
ABLA, ABGR
Low
D
Mature forest;
PIEN, PICO,
PSME, LAOC,
ABLA, ABGR
Low
E
Near climax;
PIEN & ABLA
overstory w/
PSME & LAOC
veterans
Low
F
Climax forest;
PIEN or ABLA
Low
LEGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 35—Hypothetical fire-related successional pathways for Fire Group Nine habitat types.

consumptive uses, such as watershed protection and wildlife habitat. On some sites the disturbances associated with modern fire suppression might result in more lasting damage than the fire would cause. Consequently, the appropriate fire management policy may be one that allows certain ignitions to burn according to a predetermined fire management prescription (Fischer 1980).

FIRE GROUP TEN: COLD, UPPER SUBALPINE AND TIMBERLINE HABITAT TYPES

ADP code	Habitat type-phase	Physiographic sections
	(Steele and others 1981)	(Steele and others 1981)
	Upper Subalpine	
810	*Abies lasiocarpa/Ribes montigenum* h.t. (ABLA/RIMO), subalpine fir/mountain gooseberry	Open Northern Rockies and Challis
831	*Abies lasiocarpa/Luzula hitchcockii* h.t. - *Vaccinium scoparium* phase (ABLA/LUHI-VASC), subalpine fir/smooth woodrush - grouse whortleberry phase	Salmon Uplands and Southern Batholith
833	*Abies lasiocarpa/Luzula hitchcockii* h.t. - *Luzula hitchcockii* phase (ABLA/LUHI-LUHI), subalpine fir/smooth woodrush - smooth woodrush phase	Salmon Uplands and Southern Batholith
34	*Abies lasiocarpa/Vaccinium scoparium* h.t. - *Pinus albicaulis* phase (ABLA/VASC-PIAL), subalpine fir/grouse whortleberry - whitebark pine phase	Southern Batholith and Challis
93	*Abies lasiocarpa/Carex geyeri* h.t. - *Artemisia tridentata* phase (ABLA/CAGE-ARTR), subalpine fir/elk sedge - big sagebrush phase	Southern Batholith, Salmon Uplands, and Challis
	Timberline	
50	*Pinus albicaulis-Abies lasiocarpa* h.t.'s (PIAL-ABLA), whitebark pine-subalpine fir	Salmon Uplands, Southern Batholith, and Challis
70	*Pinus albicaulis* Series (PIAL h.t.'s), whitebark pine	Challis and Open Northern Rockies

Vegetation

Fire Group Ten habitat types occur at or near upper timberline. Severe winds, low temperature, and thin soils all contribute to harsh site conditions. On exposed dry ridges conditions are even more harsh.

In cirque basins and on north slopes near timberline, trees characteristically grow as islands interspersed with open meadows (Arno and Hammerly 1984). Above these areas lie krummholz. In some areas whitebark pine is the only tree present while other areas support clusters of whitebark pine and subalpine fir (fig. 36). Individual stands of whitebark pine may be 500 or more years old, with high basal areas and biomass (Forcella and Weaver 1977).

In the upper subalpine forests, subalpine fir is the indicated climax. Succession is slow, and stands tend to remain open; thus seral species seldom disappear. Whitebark pine, lodgepole pine, spruce, and occasionally Douglas-fir may all be seral. Limber pine may occur on limestone substrate in the Open Northern Rockies physiographic section. Spruce is also more prevalant in the Open Northern Rockies.

Stands are generally open, with mountain gooseberry, grouse whortleberry, mountain snowberry, and big sagebrush the most common shrubs. Broadleaf arnica, woodrush, snowlover, coiled lousewort, Parry rush, elk sedge, false-hellebore, pokeweed fleece-flower, Idaho fescue, and western needlegrass are found in the herbaceous layer.

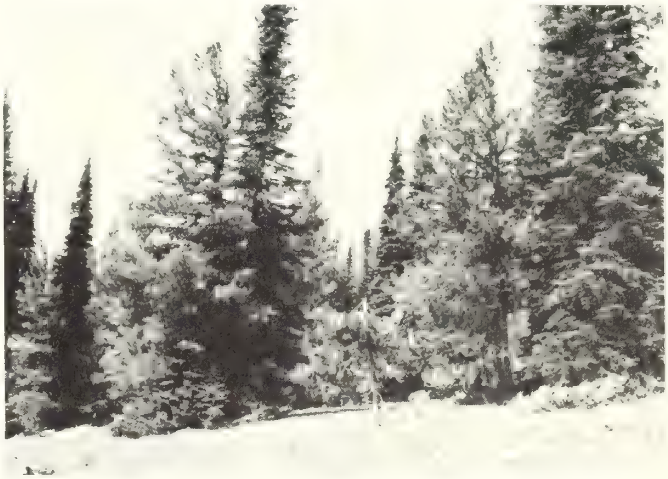


Figure 36—A PIAL-ABLA forest in the vicinity of Cloochman Creek Road, Payette National Forest.

Forest Fuels

Fuel inventory data for Group Ten habitat types are scarce. Data from stands in the Selway-Bitterroot Wilderness in western Montana and central Idaho showed a wide range of downed woody fuel loadings. The average total loading for 153 plots in three different habitat types was about 14 tons/acre (3.14 kg/m^2); material greater than 3 inches (7.6 cm) in diameter accounted for 11 tons/acre (2.47 kg/m^2) of this total. Fuels tend to be very discontinuous. Typically, most of the fuel load is the result of a few, scattered, large-diameter downfalls resulting from wind and snow breakage, windthrow, and insect- and disease-caused mortality. Such fuels do not reflect a serious fire hazard. The usually sparse and often discontinuous nature of fine surface fuels (live or dead), the short fire season, and the normally cool, moist site are mitigating factors that must be considered.

Role of Fire

The severity of Group Ten sites and the prevailing climate near and at timberline minimize the possibility of severe fires. Lightning does ignite fires, but the patchiness of trees and fuel, the short fire season, and the prevalance of rain showers with lightning storms limit the number of fires and their spread. Gabriel (1976) concluded that the fire history at high elevations in the Bob Marshall Wilderness was one of lightning strikes igniting many fires that burned small patches, ranging from a single tree to a few acres.

In the more continuous forests of this Fire Group, the most pronounced fire effect is to produce stand-replacing fires at long intervals of 100 to 300 years (Heinselman 1981). Stand-destroying fires in Group Ten are most likely to occur during extended periods of drought when very severe wind-driven crown fires develop in the forests below and burn into the upper subalpine and timberline forests. Vegetational recovery following such fires is usu ly slow because of the extremely short growing season a cold climate. The wet or dry subalpine meadow that for the early successional stage may last a century or more (Billings 1969; Stahelin 1943).

Forest Succession

Secondary succession begins with a mixture of herbs a shrubs, and possibly some conifer seedlings in the shelter of snags, logs, or shrubs (fig. 37). Herbaceous plants will probably prevail for an extended period. Fire may initiat secondary succession but probably will not maintain it. O moist sites and north slopes physical disruption of the stand by snow and wind, and snow and rock slides is mo important than fire in maintaining early stages of succession.

Perhaps 100 years or more will elapse before conifers dominate some Group Ten sites. It may take another century for a mature forest to develop. It is unlikely that fu or stand conditions will support a fire of any consequenc during this period. Surface fires do occur, especially in whitebark pine stands on south slopes and ridges. Such fires act as underburns reducing fuels and killing some overstory trees. Severe fires may occur over small areas, but their effect will usually be limited to the creation of

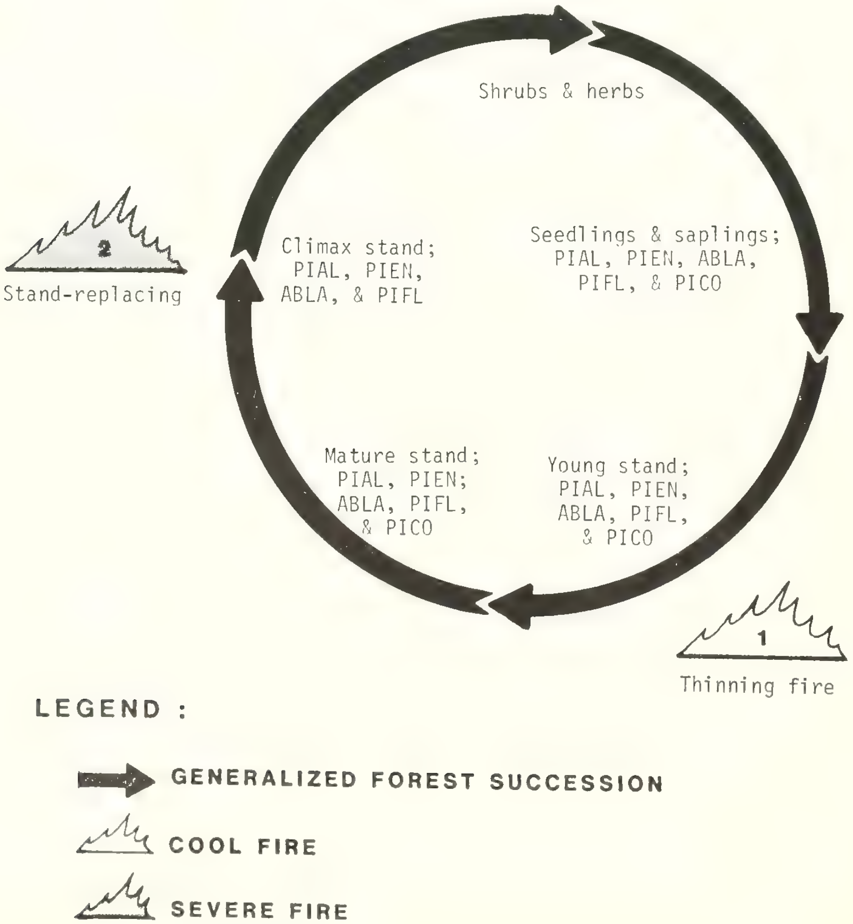

Shrubs & herbs
Seedlings & saplings; PIAL, PIEN, ABLA, PIFL, & PICO
Young stand; PIAL, PIEN, ABLA, PIFL, & PICO
Mature stand; PIAL, PIEN; ABLA, PIFL, & PICO
Climax stand; PIAL, PIEN, ABLA, & PIFL
2
Stand-replacing
1
Thinning fire
LEGEND :
GENERALIZED FOREST SUCCESSION
COOL FIRE
SEVERE FIRE

Figure 37—Generalized forest succession for Fire Group Ten: cold upper subalpine and timberline habitat types.

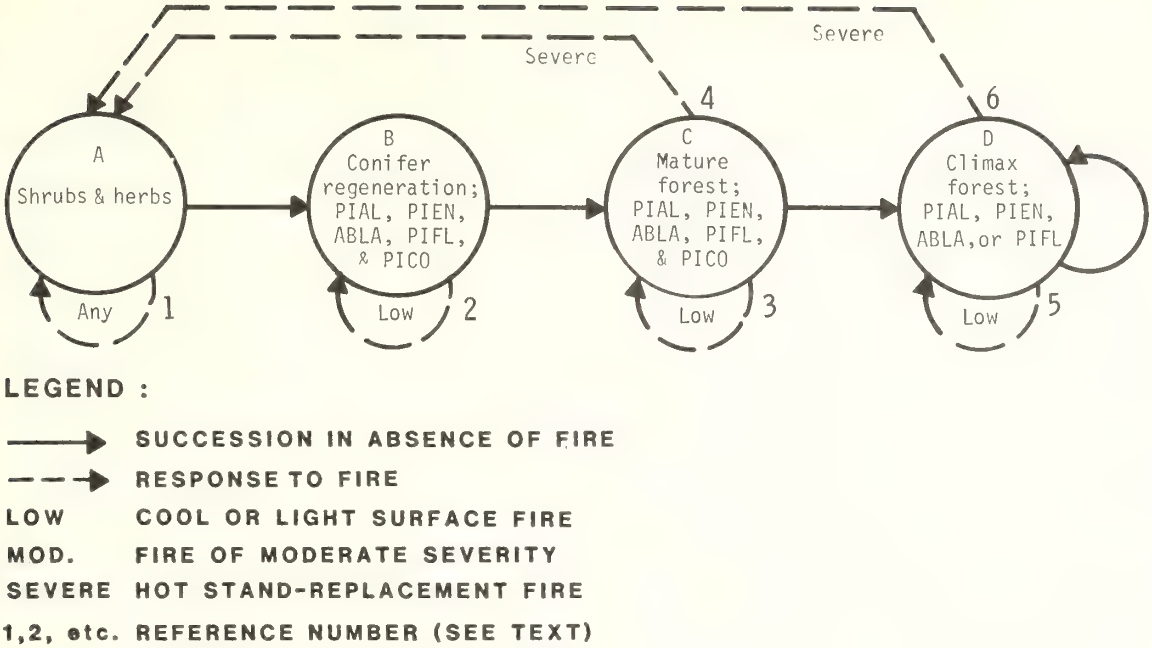

Severe
Severe
4
6
A
Shrubs & herbs
B
Conifer regeneration;
PIAL, PIEN,
ABLA, PIFL,
& PICO
C
Mature forest;
PIAL, PIEN,
ABLA, PIFL,
& PICO
D
Climax forest;
PIAL, PIEN,
ABLA, or PIFL
Any
1
Low
2
Low
3
Low
5
LEGEND :
SUCCESSION IN ABSENCE OF FIRE
RESPONSE TO FIRE
LOW COOL OR LIGHT SURFACE FIRE
MOD. FIRE OF MODERATE SEVERITY
SEVERE HOT STAND-REPLACEMENT FIRE
1,2, etc. REFERENCE NUMBER (SEE TEXT)

Figure 38—Hypothetical fire-related successional pathways for Fire Group Ten habitat types.

getative mosaics. Eventually the mature forest will gin to break up under the impact of wind and snow eakage, windthrow, insect and disease attacks, and nescence. Stand-destroying fires, especially those that ade from low-elevation forests become a possibility dur- periods of extended drought.

Without disturbance, the mature trees will progress into limax stand. This advanced successional stage requires cades, and sometimes centuries. Fires of low-to- derate severity rarely affect a mature stand because of open structure and lack of continuous fine woody ls; however, severe fires that enter the crowns and kill cambium of trees return the site to the early succes- nal stages (fig. 37).

simple successional pathway postulated for Fire Group n is shown in figure 38.

Fire Management Considerations

Timber production is rarely an important management objective in Fire Group Ten forests. Watershed, wildlife, and recreation are often the dominant values. Consumptive uses are often restricted by natural area or wilderness designation. Fire is infrequent, and when it does occur damage in terms of management objectives is usually slight. These sites are, however, fragile and can easily be damaged by modern, mechanized firefighting equipment.

For many Group Ten habitats, the primary fire management consideration should be the development of prescriptions that allow fire to more nearly play its natural role (Fischer 1984).

REFERENCES

Aho, Paul E. Decay of grand fir in the Blue Mountains of Oregon and Washington. Research Paper PNW-229. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1977. 18 p.

Alexander, M. E.; Hawksworth, F. G. Wildland fires and dwarf mistletoes: a literature review of ecology and prescribed burning. General Technical Report RM-14. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 12 p.

Alexander, Robert T.; Shepperd, Wayne D. Silvical characteristics of Engelmann spruce. General Technical Report RM-114. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1984. 38 p.

Allen, A. W. Habitat suitability index models: southern red-backed vole (western United States). FSW/OBS-82/10.42. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1983. 14 p.

Amman, G. D. The role of mountain pine beetle in lodgepole pine ecosystems: impact on succession. In: Mattson, W. J., ed. Proceedings in life sciences: the role of arthropods in forest ecosystems. New York: Springer-Verlag; 1977: 3-15.

Armour, C. D.; Bunting, S. C.; Neuenschwander, L. F. Fire intensity effects on the understory in ponderosa pine forests. Journal of Range Management. 37(1): 44-49; 1984.

Arno, Stephen F. The historical role of fire in the Bitterroot National Forest. Research Paper INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 29 p.

Arno, Stephen F. Forest fire history in the northern Rockies. Journal of Forestry. 78(8): 460-465; 1980.

Arno, Stephen F. Whitebark pine cone crops—a diminishing source of wildlife food? Western Journal of Applied Forestry. 1(3): 92-94; 1986.

Arno, Stephen F.; Gruell, George E. Fire history at the forest-grassland ecotone in southwestern Montana. Journal of Range Management. 36(3): 332-336; 1983.

Arno, Stephen F.; Hammerly, Romona P. Timberline. Seattle, WA: The Mountaineers; 1984. 304 p.

Arno, S. F.; Hoff, R. J. Whitebark pine. In: Silvics of forest trees of the United States. Agriculture Handbook. Washington, DC: U.S. Department of Agriculture, Forest Service; [in press].

Arno, S. F.; Peterson, T. D. Variation in estimates of fire intervals: a closer look at fire history on the Bitterroot National Forest. Research Paper INT-301. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 8 p.

Arno, Stephen F.; Simmerman, Dennis G.; Keane, Robert E. Forest succession on four habitat types in western Montana. General Technical Report INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 74 p.

Arno, Stephen F.; Wilson, Andrew E. Dating past fires i curlleaf mountain-mahogany communities. Journal of Range Management. 39(3): 240-243; 1986.

Barrett, Stephen W. Fire history of the River of No Return Wilderness: River Breaks Zone. Missoula, MT: Systems for Environmental Management; 1984; Final Report. 40 p. [Unpublished.]

Beechman, J. J.; Reynolds, D. G.; Hornocker, M. G. Blac bear denning activities and den characteristics in west-central Idaho. In: Proceedings, International Conferenc on Bear Research and Management. 5: 79-86; 1984.

Bendell, J. F. Effects of fire on birds and mammals. Chapter 4. In: Kozlowski, T. T.; Ahlgren, C. E., eds. Fire and ecosystems. New York: Academic Press; 1974

Bernard, S. R.; Brown, K. F. Distribution of mammals, reptiles, and amphibians by BLM physiographic regions and A. W. Kuchler's associations for the eleven wester States. Technical Note 301. Denver, CO: U.S. Department of the Interior, Bureau of Land Management; 1977. 168 p.

Billings, W. D. Vegetational patterns near alpine timberline as affected by fire-snowdrift interactions. Vegetati 19: 192-207; 1969.

Black, H. C.; Taber, R. D. Mammals in western conifero forest ecosystems: an annotated bibliography. Bulletin No. 2. Coniferous Forest Biome Ecosystem Analysis Studies, U.S. International Biological Program. Seattle WA: University of Washington; 1977. 199 p.

Boss, A.; Dunbar, M.; Gacey, J.; Hanna, P.; Roth, M.; Grossarth, O. D. Elk-timber relationships of west-centr Idaho. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests; U.S. Department of the Interior, Bureau of Land Management; 1983. 34 p.

Bradley, A. Rhizome depth and potential fire survival of eight woody understory plants in Montana. Missoula, MT: University of Montana; 1984. 184 p. M.A. thesis.

Britton, C. M.; Clark, R. G.; Sneva, F. A. Effects of soil moisture on burned and clipped Idaho fescue. Journal Range Management. 36(6): 708-710; 1983.

Brown, A. A.; Davis, K. P. Forest fire: control and use. New York: McGraw-Hill; 1973. 686 p.

Brown, J. K. Fire cycles and community dynamics in lodgepole pine forests. In: Baumgartner, D. M., ed. Management of lodgepole pine ecosystems: Proceeding of a symposium; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperat Extension Service; 1975: 429-456.

Brown, James K.; Marsden, Michael A.; Ryan, Kevin C. Reinhardt, Elizabeth D. Predicting duff and woody fu consumed by prescribed fire in the Northern Rocky Mountains. Research Paper INT-337. Ogden, UT: U.S Department of Agriculture, Forest Service, Intermou tain Forest and Range Experiment Station; 1985. 23

Brown, James K.; See, Thomas. Downed dead woody fu and biomass in the Northern Rocky Mountains. Gener Technical Report INT-117. Ogden, UT: U.S. Departm of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 48 p.

Carlton, D. W.; Pickford, S. G. Fuelbed changes with aging of slash from ponderosa pine thinnings. Journal Forestry. 80(2): 91-107; 1982.

attelino, P. U.; Noble, I. R.; Slatyer, R. D.; Kessell, S. R. Predicting the multiple pathways of plant succession. Environmental Management. 3: 41-50; 1979.

handler, C.; Cheney, P.; Thomas, P.; Trabaud, L.; Williams, D. Fire in forestry. Vol. I. Forest fire behavior and effects. New York: John Wiley and Sons; 1983. 450 p.

layton, J. L.; Megahan, W. F.; Hampton, D. Soil and bedrock properties: weathering and alteration products and processes in the Idaho batholith. Research Paper INT-237. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 35 p.

lements, F. E. The life history of lodgepole pine burn forest. Forest Service Bulletin 79. Washington, DC: U.S. Department of Agriculture, Forest Service; 1910. 56 p.

ole, D. M. Feasibility of silvicultural practices for reducing losses to the mountain pine beetle in lodgepole pine forests. In: Theory and practice of mountain pine beetle management in lodgepole pine forests: Proceedings of the symposium; 1978 April 25-27; Pullman, WA. Pullman, WA: Washington State University; 1978: 140-146.

ole, Walter E.; Amman, Gene D. Mountain pine beetle dynamics in lodgepole pine forests. Part I: Course of an infestation. General Technical Report INT-89. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 56 p.

onnaughton, C. A. Fire damage in the ponderosa pine type in Idaho. Journal of Forestry. 34: 46-51; 1936.

ooper, S. V. Forest habitat types of northwestern Wyoming and contiguous portions of Montana and Idaho. Pullman, WA: Washington State University; 1975. 190 p. Ph.D. dissertation.

rane, M. F.; Habeck, J. R.; Fischer, W. C. Early postfire revegetation in a western Montana Douglas-fir forest. Research Paper INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 32 p.

aniels, J. D. Variation and intergradation in the grand fir-white fir complex. Moscow, ID: University of Idaho; 1969. 235 p. Ph.D. dissertation.

aubenmire, R. F. Vegetation zonation in the Rocky Mountains. Botanical Review. 9: 325-393; 1943.

aubenmire, R.; Daubenmire, J. B. Forest vegetation of eastern Washington and northern Idaho. Technical Bulletin 60. Pullman, WA: Washington Agricultural Experiment Station, Washington State University; 1968. 104 p.

avis, Kathleen M.; Clayton, Bruce D.; Fischer, William C. Fire ecology of Lolo National Forest habitat types. General Technical Report INT-79. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 77 p.

avis, R. J. Flora of Idaho. Dubuque, IA: Wm. C. Brown Co.; 1952. 836 p.

eByle, Norbert V.; Bevins, Collin D.; Fischer, William C. Wildfire occurrence in aspen stands in the interior western States. Western Journal of Applied Forestry. [In press.]

Despain, D. G. Vegetation of the Big Horn Mountain, Wyoming, in relation to substrate and climate. Ecological Monographs. 43: 329-355; 1973.

Despain, D. G.; Sellers, R. E. Natural fire in Yellowstone National Park. Western Wildlands. 4(1): 20-24; 1977.

Eggler, W. A. Primary succession on volcanic deposits in southern Idaho. Ecological Monographs. 11: 277-298; 1941.

Fellin, David G. A review of some relationships of harvesting, residue management, and fire to forest insects and disease. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: Symposium proceedings; 1979 September 11-13; Missoula, MT. General Technical Report INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 335-414.

Fischer, William C. Planning and evaluating prescribed fires—a standard procedure. General Technical Report INT-43. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978. 19 p.

Fischer, W. C. Fire management techniques for the 1980's. The Ames Forester. Ames, IA: Iowa State University, Forestry Club; 66: 23-28; 1980.

Fischer, William C. Prescribed fire and bark beetle attack in ponderosa pine forests. Fire Management Notes. 41(2): 10-12; 1980.

Fischer, William C. Photo guide for appraising downed woody fuels in Montana forests: interior ponderosa pine, ponderosa pine-larch-Douglas-fir, larch-Douglas-fir, and interior Douglas-fir cover types. General Technical Report INT-97. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981a. 133 p.

Fischer, William C. Photo guide for appraising downed woody fuels in Montana forests: grand fir-larch-Douglas-fir, western hemlock, western redcedar-western hemlock, and western redcedar cover types. General Technical Report INT-96. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981b. 53 p.

Fischer, William C. Photo guide for appraising downed woody fuels in Montana forests: lodgepole pine and Engelmann spruce-subalpine fir cover types. General Technical Report INT-98. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981c. 143 p.

Fischer, William C. Wilderness fire management planning guide. General Technical Report INT-171. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 56 p.

Fischer, W. C.; Clayton, B. D. Fire ecology of Montana forest habitat types east of the Continental Divide. General Technical Report INT-141. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 210 p.

Fisher, G. M. Comparative germination of tree species on various kinds of surface soil material in the western white pine type. Ecology. 16: 606-611; 1935.

Flint, H. R. Fire resistance of Northern Rocky Mountain conifers. Journal of Forestry. 7: 7-10, 41-43; 1925.

Forcella, F.; Weaver, T. Biomass and productivity of the subalpine *Pinus albicaulis-Vaccinium scoparium* association in Montana. Vegetatio. 35: 95-105; 1977.

Frederick, D. J. Some ecological factors and external tree characters relating to defect in grand fir in central Idaho. Moscow, ID: University of Idaho; 1972. 59 p. Ph.D. dissertation.

Freedman, J. D. The historical relationship between fire and plant succession within the Swan Valley white-tailed deer winter range, western Montana. Missoula, MT: University of Montana; 1983. 137 p. Ph.D. dissertation.

Gabriel, H. W., III. Wilderness ecology: the Danaher Creek drainage, Bob Marshall Wilderness, Montana. Missoula, MT: University of Montana; 1976. 224 p. Ph.D. dissertation.

Gonsior, M. J.; Gardner R. B. Investigation of slope failures in the Idaho Batholith. Research Paper INT-97. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971. 34 p.

Gray, D. H.; Megahan, W. F. Forest vegetation removal and slope stability in the Idaho batholith. Research Paper INT-271. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 23 p.

Gruell, George E. Post-1900 mule deer irruptions in the Intermountain West: principal causes and influences. General Technical Report INT-206. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 37 p.

Gruell, George; Schmidt, Wyman C.; Arno, Stephen; Reich, William J. Seventy years of vegetative change in a managed ponderosa pine forest in western Montana—implications for resource management. General Technical Report INT-130. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 42 p.

Habeck, J. R.; Mutch, R. W. Fire dependent forests in the Northern Rocky Mountains. Quaternary Research. 3: 408-424; 1973.

Hall, Dale O. Ponderosa pine planting techniques, survival, and height growth in the Idaho batholith. Research Paper INT-104. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971. 28 p.

Hall, F. C. Fire and vegetation in the Blue Mountains—implications for land managers. In: Proceedings of Tall Timbers Fire Ecology Conference No. 15; 1974 October 16-17; Portland, OR. Tallahassee, FL: Tall Timbers Research Station; 1976: 155-170.

Hall, F. C. Fire history—Blue Mountains, Oregon. In: Proceedings, fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 75-81.

Halvorson, C. H. Small mammal populations. In: DeByle, N. V. Clearcutting and fire in the larch/Douglas-fir forests of western Montana. General Technical Report INT-99. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest Range Experiment Station; 1981: 41-46.

Halvorson, C. H. Rodent occurrence, habitat disturba and seed fall in a larch-fir forest. Ecology. 63(2): 423-433; 1982.

Hamilton, J. [Personal communication.] 1985. On file Intermountain Fire Sciences Laboratory, Intermou Research Station, Forest Service, U.S. Department Agriculture, Missoula, MT.

Harvey, Alan E. The importance of residual organic in site preparation and amelioration for reforestati In: Baumgartner, David M., ed. Site preparation a fuels management on steep terrain: Proceedings of symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Coope Extension; 1982: 75-85.

Harvey, A. E.; Jurgensen, M. F.; Larsen, M. J. Orga reserves: importance to ectomycorrhizae in forest s of western Montana. Forest Science. 27: 442-445; 1

Hawksworth, F. G. Rate of spread and intensificatio dwarfmistletoe in young lodgepole pine stands. Jou of Forestry. 56: 404-407; 1958.

Hawksworth, F. G.; Hinds, T. E. Effects of dwarfmistletoe on immature lodgepole pine stands in Colorado. Journal of Forestry. 62: 27-32; 1964.

Heinselman, M. L. Fire intensity and frequency as fa in the distribution and structure of northern ecosys In: Fire regimes and ecosystem properties: Procee of the conference; 1978 December 11-15; Honolulu, General Technical Report WO-26. Washington, DC Department of Agriculture, Forest Service; 1981: 7

Hironaka, M.; Fosberg, M. A.; Winward, A. H. Sage grass habitat types of southern Idaho. Bulletin 35. Moscow, ID: University of Idaho, College of Fores Wildlife, and Range Sciences; 1983. 44 p.

Hobbs, N. T.; Spowart, R. A. Effects of prescribed f nutrition of mountain sheep and mule deer during and spring. Journal of Wildlife Management. 48(2): 551-568; 1984.

Holdorf, Hubert. Effects of site prepartion and fuel management practices on soil productivity. In: Baumgartner, David M., ed. Site preparation and f management on steep terrain: Proceedings of the s posium; 1982 February 15-17; Spokane, WA. Pullm WA: Washington State University, Cooperative Ex sion; 1982: 63-65.

Hutchins, H. E.; Lanner, R. M. The central role of C nutcracker in the dispersal and establishment of w bark pine. Oecologia. 55: 192-201; 1982.

Kelsal, J. P.; Telfer, E. S.; Wright, T. D. The effects fire on the ecology of the boreal forest with partic reference to the Canadian North: a review and sele bibliography. Occasional Paper 32. Ottawa, ON: Ca dian Wildlife Service, Fisheries and Environment; 58 p.

Keown, L. D. Interim report: Blacktail Hills prescrib fire project, implementation and results. Great Fal MT: U.S. Department of Agriculture, Forest Servi Lewis and Clark National Forest; 1977. 9 p. [Mime

Keown, L. D. Fire management in the Selway-Bitter Wilderness. Grangeville, ID: U.S. Department of Agriculture, Forest Service, Nez Perce National F 1978. 34 p.

essell, Stephen R.; Fischer, William C. Predicting postfire plant succession for fire management planning. General Technical Report INT-94. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 19 p.

emmedson, J. O.; Smith, J. G. Cheatgrass (*Bromus tectorum* L.). Botanical Review. 30: 226-262; 1964.

oonce, A. L. Interactions between fire and dwarf mistletoe in ponderosa pine. Corvallis, OR: Oregon State University; 1981. 53 p. Ph.D. thesis.

amer, Neal B. Mature forest seed banks on three habitat types in central Idaho. Moscow, ID: University of Idaho; 1984. 107 p. M.A. thesis.

amp, B. A.; Patton, D. R.; Brady, W. W. The effects of fire on wildlife habitat and species. Run Wild/Wildlife Habitat Relationships Technical Report. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region; 1983. 29 p.

glin, J. Beetles eat their way along Montana's backbone. The Missoulian. 1980 January 17; Sect. B: 23.

ngenheim, J. H. Vegetation and environmental patterns in the Crested Butte area, Gunnison County, Colorado. Ecological Monographs. 32: 249-285; 1962.

nner, R. M. Adaptations of whitebark pine for seed dispersal by Clark's nutcracker. Canadian Journal of Forest Research. 12: 391-402; 1982.

nner, R. M.; Vander-Wall, S. B. Dispersal of limber pine seed by Clark's nutcracker. Journal of Forestry. 78(10): 637-639; 1980.

tan, J. E. The role of cone serotiny in lodgepole pine forests. In: Baumgartner, D. M., ed. Management of lodgepole pine ecosystems: Proceedings of the symposium; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1975: 471-496.

tan, J. E.; Alexander, M. E.; Arno, S. F.; [and others]. Effects of fire on flora: a state-of-knowledge review. General Technical Report WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981. 71 p.

tan, J. E.; Perry, D. A. Ecology and regeneration of lodgepole pine. Agriculture Handbook 606. Washington, DC: U.S. Department of Agriculture, Forest Service; 1983. 51 p.

on, L. J. Initial vegetal development following prescribed burning of Douglas-fir in south-central Idaho. Research Paper INT-29. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1966. 17 p.

on, L. J. Vegetal development following prescribed burning of Douglas-fir in south central Idaho. Research Paper INT-105. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971. 30 p.

on, L. Jack. Attrition of lodgepole pine snags on the Sleeping Child Burn, Montana. Research Note INT-219. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 4 p.

on, L. Jack. The Sleeping Child Burn—21 years of postfire change. Research Note INT-330. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 17 p.

Lyon, L. Jack; Crawford, H. S.; Czuhai, R.; [and others]. Effects of fire on fauna: a state-of-knowledge review. General Technical Report WO-6. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 22 p.

Lyon, L. Jack; Stickney, Peter F. Early vegetal succession following large northern Rocky Mountain wildfires. In: Proceedings, Tall Timbers Fire Ecology Conference No. 14; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station; 1976: 355-375.

Martin, Robert E. Shrub control by burning before timber harvest. In: Baumgartner, David M., ed. Site preparation and fuels management on steep terrain: Proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1982: 35-40.

Maser, C.; Mate, B. R.; Franklin, J. F.; Dyrness, C. T. Natural history of Oregon coast mammals. General Technical Report PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 496 p.

Mathews, Edward E. The accretion of fuel in lodgepole pine forests in southwest Montana. Missoula, MT: University of Montana; 1980. 39 p. M.S. thesis.

Maupin, John. Stage underburning in ponderosa pine. Fire Management Notes. 42(3): 16-17; 1981.

McClelland, B. R.; Frissell, S. S. Identifying forest snags useful for hole-nesting birds. Journal of Forestry. 73(7): 414-417; 1975.

McClelland, B. R.; Frissell, S. S.; Fischer, W. C.; Halvorson, C. H. Habitat management for hole-nesting birds in forests of western larch and Douglas-fir. Journal of Forestry. 77(8): 480-483; 1979.

McGregor, Mark D.; Cole, Dennis M., eds. Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. General Technical Report INT-174. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 68 p.

McLean, Alastair. Fire resistance of forest species as influenced by root systems. Journal of Range Management. 22(2): 120-122; 1969.

Megahan, W. F. Erosion over time on severely disturbed granitic soils: a model. Research Paper INT-156. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 14 p.

Megahan, W. F. Hydrologic effects of clearcutting and wildfire on steep granitic slopes in Idaho. Water Resources Research. 19(3): 811-819; 1983.

Megahan, W. F.; Day, N. F.; Bliss, T. M. Landslide occurrence in the western and central Northern Rocky Mountain physiographic province in Idaho. In: Youngberg, C. T., ed. Forest soils and land use: Proceedings of 5th North American forest soils conference; Fort Collins, CO. Fort Collins, CO: Colorado State University, Department of Forestry and Wood Sciences; 1978: 116-139.

Melquist, W. E.; Hornocker, M. G. Ecology of river otters in west-central Idaho. Wildlife Monographs. 83: 1-60; 1983.

Miller, M. Response of blue huckleberry to prescribed fires in a western Montana larch-fir forest. Research Paper INT-188. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 33 p.

Minore, Don. Comparative autecological characteristics of northwestern tree species—a literature review. General Technical Report PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 72 p.

Morgan, P.; Neuenschwander, L. F. Seedbank contribution to shrub regeneration following clearcutting and burning. 1984. Unpublished report on file at: Department of Forest Resources, University of Idaho, Moscow, ID.

Mueggler, W. F. Ecology of seral shrub communities in the cedar-hemlock zone of northern Idaho. Ecological Monographs. 35: 165-185; 1965.

Muraro, S. J. The lodgepole pine fuel complex. Information Report BC-X-53. Victoria, BC: Canadian Forest Service, Department of Fisheries and Forestry, Forest Research Laboratory; 1971. 35 p.

Nord, E. C. Autecology of bitterbrush in California. Ecological Monographs. 35: 307-334; 1965.

Noste, Nonan V. Influence of fire severity on response of evergreen ceanothus. In: Lotan, James E.; Brown, James K., compilers. Fire's effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. General Technical Report INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985: 91-96.

Oberheu, Rick D.; Mutch, Robert W. Appendix D: Summary of Teton Wilderness by fuels, vegetation, topography, rate of spread, intensity, and burnout potential. In: Reese, Jerry B.; Mohr, Francis R.; Dean, Ronald E.; Klabunde, Thomas. Teton Wilderness fire management plan. Jackson, WY: U.S. Department of Agriculture, Forest Service, Bridger-Teton National Forest; 1976. 26 p.

Peek, J. M.; Johnson, F. D.; Pence, N. N. Successional trends in a ponderosa pine/bitterbrush community related to grazing by livestock, wildlife and to fire. Journal of Range Management. 31(1): 49-53; 1978.

Peek, J. M.; Demarchi, D. A.; Demarchi, R. A.; Stucker, D. E. Bighorn sheep and fire: seven case studies. In: Lotan, James E.; Brown, James K., compilers. Fire's effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. General Technical Report INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985: 36-43.

Perry, D. A.; Lotan, J. E. Opening temperatures in serotinous cones of lodgepole pine. Research Note INT-228. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 6 p.

Petersen, D. L. Predicting fire-caused mortality in four northern Rocky Mountain conifers. In: New forests for a changing world: Proceedings 1983 convention of the Society of American Foresters; 1983 October 16-20; Portland, OR. Washington, DC: Society of American Foresters; 1984: 276-280.

Pfister, R. D.; Daubenmire, R. Ecology of lodgepole pir In: Baumgartner, D. M., ed. Management of lodgepol pine ecosystems: Proceedings of the symposium; 1973 October 9-11; Pullman, WA. Pullman, WA: Washingt State University, Cooperative Extension Service; 197 27-46.

Rehfeldt, G. E. Genetic variation of Douglas-fir in the Northern Rocky Mountains. Research Note INT-184. Ogden, UT: U.S. Department of Agriculture, Forest vice, Intermountain Forest and Range Experiment St tion; 1974. 6 p.

Ream, C. H. The effects of fire and other disturbances small mammals and their predators: an annotated bibliography. General Technical Report INT-106. Ogd UT: U.S. Department of Agriculture, Forest Service, termountain Forest and Range Experiment Station; 1981. 55 p

Ream, C. H.; Gruell, G. E. Influence of harvesting and residue treatments on small mammals and implicatio on forest management. In: Environmental consequen of timber harvesting in Rocky Mountain coniferous forests: Proceedings of a symposium; 1979 Septembe 11-13; Missoula, MT. General Technical Report INT-9 Ogden, UT: U.S. Department of Agriculture, Forest vice, Intermountain Forest and Range Experiment S tion; 1980: 455-467.

Roe, Arthur L.; Alexander, Robert R.; Andrews, Milto Engelmann spruce regeneration practices in the Roc Mountains. Production Research Report 115. Washin ton, DC: U.S. Department of Agriculture, Forest Ser vice; 1970. 32 p.

Roe, Arthur L.; Schmidt, Wyman C. Factors affecting natural regeneration of spruce in the Intermountain Region. Ogden, UT: U.S. Department of Agriculture Forest Service, Intermountain Forest and Range Ex ment Station; 1964. 68 p. [Mimeo.]

Romme, W. H. Fire and landscape diversity in subalpi forests of Yellowstone National Park. Ecological Monographs. 52(2): 199-221; 1982.

Romme, William H.; Knight, Dennis H. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology. 62(2): 319-326; 1981.

Roth, L. F. Juvenile susceptibility of ponderosa pine to dwarf mistletoe. Phytopathology. 64: 689-692; 1974a

Roth, L. F. Resistance of ponderosa pine to dwarf mistletoe. Silvae Genetica. 23: 116-120; 1974b.

Rowe, J. S. Concepts of fire effects on plant individua and species. In: The role of fire in northern circump ecosystems. SCOPE 18. New York: John Wiley & S 1983: 135-154.

Ryker, R. A. A survey of factors affecting regeneratic Rocky Mountain Douglas-fir. Research Paper INT-17 Ogden, UT: U.S. Department of Agriculture, Forest vice, Intermountain Forest and Range Experiment S tion; 1975. 19 p.

Ryker, R. A.; Losensky, J. Ponderosa pine and Rocky Mountain Douglas-fir. In: Burns, R. M., tech. compil Silvicultural systems for the major forest types of th United States. Agriculture Handbook 445. Washingt DC: U.S. Department of Agriculture, Forest Service 1983: 53-55.

ːy, Robert E. Intensity of bark beetle attack following escribed understory burning in seral ponderosa pine ands in north Idaho. Moscow, ID: University of Idaho; '81. 28 p. M.S. thesis.

wennesen, D. Epidemics part of forest evolution, erson says. The Missoulian [Missoula, MT]. 1979 :tober 24.

ck [Davis], Kathleen M. The fire history of Coram Ex- rimental Forest. Missoula, MT: University of Montana; '77. 134 p. M.S. thesis.

ety of American Foresters. Terminology of forest ience, technology, practice, and products; English- nguage version. The Multilingual Forestry Terminology ries No. 1. Washington, DC: Society of American oresters; 1971. 349 p.

ety of American Foresters. Forest terminology: a ossary of technical terms used in forestry. 3d ed. ashington, DC: Society of American Foresters; 1958. ' p.

ıelin, R. Factors influencing the natural restocking of gh altitude burns by coniferous trees in the Central ocky Mountains. Ecology. 24(1): 19-30; 1943.

ːker, T. J. Fire resistance in the forest. Journal of orestry. 32: 462-467; 1934.

ele, R. *Pinus flexilis* James. In: Burns, R. E., ed. lvics of native and naturalized trees of the United ates and Puerto Rico. Agriculture Handbook 271 ev.). Washington, DC: U.S. Department of Agriculture, orest Service; [in press].

ele, R.; Arno, S.; Geier-Hayes, K. Wildfire patterns ıange in central Idaho's ponderosa pine-Douglas-fir rest. Western Journal of Applied Forestry. 1(1): 16-18; 986.

ele, R.; Cooper, S. V.; Ondov, D. M.; Roberts, D. W.; fister, R. D. Forest habitat types of eastern Idaho- estern Wyoming. General Technical Report INT-144. gden, UT: U.S. Department of Agriculture, Forest Ser- ce, Intermountain Forest and Range Experiment Sta- on; 1983. 122 p.

ele, R.; Geier-Hayes, K. The grand fir/blue huckleberry abitat type: succession and management. 1982a. Un- ıblished preliminary report on file at: U.S. Department Agriculture, Forest Service, Intermountain Forest nd Range Experiment Station, Boise, ID. 57 p.

ele, R.; Geier-Hayes, K. The Douglas-fir/ninebark abitat type: succession and management. 1982b. Un- ublished preliminary report on file at: U.S. Department f Agriculture, Forest Service, Intermountain Forest nd Range Experiment Station, Boise, ID. 83 p.

ele, R.; Pfister, R. D.; Ryker, R. A.; Kittams, J. A. orest habitat types of central Idaho. General Technical eport INT-114. Ogden, UT: U.S. Department of griculture, Forest Service, Intermountain Forest and ange Experiment Station; 1981. 138 p.

vens, R. D.; Hall, R. C. Beetles and burned timber. fiscellaneous Paper 49. Berkeley, CA: U.S. Department f Agriculture, Forest Service, Pacific Southwest Forest nd Range Experiment Station; 1960. 2 p.

ːkney, P. F. Vegetative recovery and development. In: eByle, N. V. Clearcutting and fire in the larch/Douglas- r forest in western Montana: a multifaceted research ımmary. General Technical Report INT-99. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981: 33-40.

Stickney, Peter F. Vegetation response to clearcutting and broadcast burning on north and south slopes at Newman Ridge. In: Baumgartner, David M., ed. Site preparation and fuel management on steep terrain: Proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension; 1982: 159-165.

Tackle, D. Silvics of lodgepole pine. Miscellaneous Publication 19. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1961. 24 p.

Tackle, D. Ecology and silviculture of lodgepole pine. Washington, DC: Proceedings of the Society of American Foresters; 1964: 112-115.

Taylor, D. L. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. Laramie, WY: University of Wyoming; 1969. 320 p. Ph.D. thesis.

Thomas, Jack Ward, ed. Wildlife habitat in managed forests of the Blue Mountains of Oregon and Washington. Agriculture Handbook 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 512 p.

Tinnin, R. O.; Knutson, D. M. Douglas-fir dwarf mistletoe is west of the Cascade Divide. Plant Disease Reporter. 57: 716-718; 1973.

Tomback, D. F. Dispersal of whitebark pine seeds by Clark's nutcracker: a mutualism hypothesis. Journal of Animal Ecology. 51: 451-467; 1982.

Tomback, D. F. Foraging stratagies of Clark's nutcracker. The Living Bird. 16: 123-161; 1977.

Tomback, D. F.; Kramer, K. A. Limber pine seed harvest by Clark's nutcracker in the Sierra Nevada: timing and foraging behavior. Condor. 82: 467-468; 1980.

U.S. Department of Agriculture, Forest Service. Silvics of forest trees of the United States. Agriculture Handbook 271. Washington, DC: U.S. Department of Agriculture; 1965. 762 p.

U.S. Department of Agriculture, Forest Service. Ponderosa pine. The Habitat Express No. 82-23. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1982. 7 p.

Vander Wall, S. B.; Balda, R. P. Coadaptations of the Clark's nutcracker and the pinyon pine for efficient seed harvest and dispersal. Ecological Monographs. 47: 89-111; 1977.

Verner, J.; Bass, A. S. California wildlife and their habitats - western Sierra Nevada. General Technical Report PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980. 439 p.

Viereck, L. A.; Dyrness, C. T., tech. eds. Ecological effects of the Wickersham Dome fire near Fairbanks, Alaska. General Technical Report PNW-90. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 71 p.

Viereck, L. A.; Schandelmeier, L. A. Effects of fire in Alaska and adjacent Canada - a literature review. BLM-Alaska Technical Report 6. Anchorage, AK: U.S.

Department of the Interior, Bureau of Land Management, Alaska State Office; 1980. 124 p.

Vogl, R. J.; Ryder, C. Effects of slash burning on conifer reproduction in Montana's Mission Range. Northwest Science. 43(3): 135-147; 1969.

Volland, L. A.; Dell, J. D. Fire effects on Pacific Northwest forest and range vegetation. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1981. 23 p.

Wagener, W. W. Preliminary guidelines for estimating the survival of fire-damaged trees. Research Note 9. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1955. 9 p.

Wagener, W. W. Guidelines for estimating the survival of fire-damaged trees in California. Miscellaneous Paper 60. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1961. 11 p.

Walter, H. Effects of fire on wildlife communities. In: Mooney, H. A.; Conrad, C. E., eds. Environmental consequences of fire and fuel management in Mediterranean ecosystems: Proceedings of the symposium; 1977 August 1-5; Palo Alto, CA. General Technical Report WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977: 183-192.

Weaver, Harold. Effects of prescribed burning in ponderosa pine. Journal of Forestry. 55: 133-137; 1957.

Weaver, Harold. Fire and its relationship to ponderosa pine. In: Proceedings, Tall Timbers Fire Ecology Conference No. 7; 1967 November 9-10; Hoberg, CA. Tallahassee, FL: Tall Timbers Research Station; 1968: 127-149.

Weir, J. R. Mistletoe injury to conifers in the Northwest. Agriculture Bulletin 360. Washington, DC: U.S. Department of Agriculture; 1916. 38 p.

Wellner, C. A. Fire history in the northern Rocky Mountains. In: The role of fire in the Intermountain West: Proceedings of the symposium; 1970 October 27-29; Missoula, MT. Missoula, MT: Intermountain Fire Research Council; 1970: 42-64.

Willms, W.; Bailey, A. W.; McLean, A.; Tucker, R. The effects of fall grazing or burning bluebunch wheatgrass range on forage selection by deer and cattle in spring. Canadian Journal of Animal Science. 60(1): 113-122; 1980.

Woodard, P. M. Effects of prescribed burning on two different-aged high-elevation plant communities in eastern Washington. Seattle: University of Washingto 1977. 228 p. Ph.D. dissertation.

Woodmansee, R. G. Clusters of limber pine trees: a hypothesis of plant-animal coaction. The Southwester Naturalist. 21(4): 511-517; 1977.

Wright, H. A. Shrub response to fire. In: Wildland shrubs—their biology and utilization. General Technic Report INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest an Range Experiment Station; 1972: 204-217.

Wright, Henry A. The effect of fire on vegetation in ponderosa pine forests: a state-of-the-art review. Scie Publication Number T-9-199. College Station, TX: Te Tech University, College of Agriculture; 1978. 21 p.

Wright, H. A. The role and use of fire in the semideser grass-shrub type. General Technical Report INT-85. Ogden, UT: U.S. Department of Agriculture, Forest vice, Intermountain Forest and Range Experiment St tion; 1980. 24 p.

Wright, H. A.; Bailey, A. W. Fire ecology and prescrib burning in the Great Plains—a research review. Gene Technical Report INT-77. Ogden, UT: U.S. Departme of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 60 p.

Wright, H. A.; Bailey, A. W. Fire ecology. New York: John Wiley and Sons; 1982. 501 p.

Wright, H. A.; Neuenschwander, L. F.; Britton, C. M. role and use of fire in sagebrush-grass and pinyon-juniper plant communities: a state-of-the-art review. General Technical Report INT-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermou tain Forest and Range Experiment Station; 1979. 48

Zager, P. The influence of logging and wildfire on griz bear habitat in northwestern Montana. Missoula, MT University of Montana; 1980. 131 p. Ph.D. dissertati

Zimmerman, G. T. Livestock grazing, fire, and their in teractions within the Douglas-fir/ninebark habitat ty northern Idaho. Moscow, ID: University of Idaho; 19 78 p. M.S. thesis.

PPENDIX A: HABITAT TYPES OF CENTRAL IDAHO

DP			Habitat types and phases	
ode[1]	Abbreviation		Scientific name	Common name
00			*PINUS FLEXILIS* SERIES	
80	PIFL/HEKL	h.t.	*Pinus flexilis/Hesperochloa kingii* h.t.	limber pine/spikefescue
50	PIFL/FELD	h.t.	*Pinus flexilis/Festuca idahoensis* h.t.	limber pine/Idaho fescue
60	PIFL/CELE	h.t.	*Pinus flexilis/Cercocarpus ledifolius* h.t.	limber pine/curlleaf mountain-mahogany
70	PIFL/JUCO	h.t.	*Pinus flexilis/Juniperus communis* h.t.	limber pine/common juniper
00			*PINUS PONDEROSA* SERIES	
20	PIPO/STOC	h.t.	*Pinus ponderosa/Stipa occidentalis* h.t.	ponderosa pine/western needlegrass
30	PIPO/AGSP	h.t.	*Pinus ponderosa/Agropyron spicatum* h.t.	ponderosa pine/bluebunch wheatgrass
40	PIPO/FEID	h.t.	*Pinus ponderosa/Festuca idahoensis* h.t.	ponderosa pine/Idaho fescue
60	PIPO/PUTR	h.t.	*Pinus ponderosa/Purshia tridentata* h.t.	ponderosa pine/bitterbrush
61	-AGSP	phase	-*Agropyron spicatum* phase	-bluebunch wheatgrass phase
62	-FEID	phase	-*Festuca idahoensis* phase	-Idaho fescue phase
95	PIPO/SYOR	h.t.	*Pinus ponderosa/Symphoricarpos oreophilus* h.t.	ponderosa pine/mountain snowberry
70	PIPO/SYAL	h.t.	*Pinus ponderosa/Symphoricarpos albus* h.t.	ponderosa pine/common snowberry
90	PIPO/PHMA	h.t.	*Pinus ponderosa/Physocarpus malvaceus* h.t.	ponderosa pine/ninebark
00			*PSEUDOTSUGA MENZIESII* SERIES	
10	PSME/AGSP	h.t.	*Pseudotsuga menziesii/Agropyron spicatum* h.t.	Douglas-fir/bluebunch wheatgrass
20	PSME/FEID	h.t.	*Pseudotsuga menziesii/Festuca idahoensis* h.t.	Douglas-fir/Idaho fescue
21	-FEID	phase	-*Festuca idahoensis* phase	-Idaho fescue phase
22	-PIPO	phase	-*Pinus ponderosa* phase	-ponderosa pine phase
80	PSME/SYOR	h.t.	*Pseudotsuga menziesii/Symphoricarpos oreophilus* h.t.	Douglas-fir/mountain snowberry
70	PSME/ARCO	h.t.	*Pseudotsuga menziesii/Arnica cordifolia* h.t.	Douglas-fir/heartleaf arnica
72	-ASMI	phase	-*Astragalus miser* phase	-weedy milkvetch phase
71	-ARCO	phase	-*Arnica cordifolia* phase	-heartleaf arnica phase
60	PSME/JUCO	h.t.	*Pseudotsuga menziesii/Juniperus communis* h.t.	Douglas-fir/common juniper
30	PSME/CAGE	h.t.	*Pseudotsuga menziesii/Carex geyeri* h.t.	Douglas-fir/elk sedge
32	-SYOR	phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
34	-PIPO	phase	-*Pinus ponderosa* phase	-ponderosa pine phase
31	-CAGE	phase	-*Carex geyeri* phase	-elk sedge phase
95	PSME/BERE	h.t.	*Pseudotsuga menziesii/Berberis repens* h.t.	Douglas-fir/Oregon grape
97	-SYOR	phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
98	-CAGE	phase	-*Carex geyeri* phase	-elk sedge phase
96	-BERE	phase	-*Berberis repens* phase	-Oregon grape phase
85	PSME/CELE	h.t.	*Pseudotsuga menziesii/Cercocarpus ledifolius* h.t.	Douglas-fir/curlleaf mountain-mahogany
20	PSME/CARU	h.t.	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass
25	-FEID	phase	-*Festuca idahoensis* phase	-Idaho fescue phase
24	-PIPO	phase	-*Pinus ponderosa* phase	-ponderosa pine phase
23	-CARU	phase	-*Calamagrostis rubescens* phase	-pinegrass phase
75	PSME/OSCH	h.t.	*Pseudotsuga menziesii/Osmorhiza chilensis* h.t.	Douglas-fir/mountain sweet-root
40	PSME/SPBE	h.t.	*Pseudotsuga menziesii/Spiraea betulifolia* h.t.	Douglas-fir/white spirea
44	-PIPO	phase	-*Pinus ponderosa* phase	-ponderosa pine phase
43	-CARU	phase	-*Calamagrostis rubescens* phase	-pinegrass phase
41	-SPBE	phase	-*Spiraea betulifolia* phase	-white spirea phase
10	PSME/SYAL	h.t.	*Pseudotsuga menziesii/Symphoricarpos albus* h.t.	Douglas-fir/common snowberry
15	-PIPO	phase	-*Pinus ponderosa* phase	-ponderosa pine phase
13	-SYAL	phase	-*Symphoricarpos albus* phase	-common snowberry phase
80	PSME/VAGL	h.t.	*Pseudotsuga menziesii/Vaccinium globulare* h.t.	Douglas-fir/blue huckleberry
90	PSME/ACGL	h.t.	*Pseudotsuga menziesii/Acer glabrum* h.t.	Douglas-fir/mountain maple
92	-SYOR	phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
93	-ACGL	phase	-*Acer glabrum* phase	-mountain maple phase
60	PSME/PHMA	h.t.	*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark
62	-CARU	phase	-*Calamagrostis rubescens* phase	-pinegrass phase
64	-PIPO	phase	-*Pinus ponderosa* phase	-ponderosa pine phase
65	-PSME	phase	-*Pseudotsuga menziesii* phase	-Douglas-fir phase
90	PSME/LIBO	h.t.	*Pseudotsuga menziesii/Linnaea borealis* h.t.	Douglas-fir/twinflower
50	PSME/VACA	h.t.	*Pseudotsuga menziesii/Vaccinium caespitosum* h.t.	Douglas-fir/dwarf huckleberry
00			*PICEA ENGELMANNII* SERIES	
93	PIEN/HYRE	h.t.	*Picea engelmannii/Hypnum revolutum* h.t.	spruce/hypnum
40	PIEN/GATR	h.t.	*Picea engelmannii/Galium triflorum* h.t.	spruce/sweetscented bedstraw
90	PIEN/CADI	h.t.	*Picea engelmannii/Carex disperma* h.t.	spruce/soft-leaved sedge
10	PIEN/EQAR	h.t.	*Picea engelmannii/Equisetum arvense* h.t.	spruce/common horsetail

(con.)

APPENDIX A. (Con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific name	Common name
500		*ABIES GRANDIS* SERIES	
585	ABGR/CARU h.t.	*Abies grandis/Calamagrostis rubescens* h.t.	grand fir/pinegrass
505	ABGR/SPBE h.t.	*Abies grandis/Spiraea betulifolia* h.t.	grand fir/white spirea
515	ABGR/VAGL h.t.	*Abies grandis/Vaccinium globulare* h.t.	grand fir/blue huckleberry
510	ABGR/XETE h.t.	*Abies grandis/Xerophyllum tenax* h.t.	grand fir/beargrass
525	ABGR/ACGL h.t.	*Abies grandis/Acer glabrum* h.t.	grand fir/mountain maple
527	-PHMA phase	-*Physocarpus malvaceus* phase	-ninebark phase
526	-ACGL phase	-*Acer glabrum* phase	-mountain maple phase
590	ABGR/LIBO h.t.	*Abies grandis/Linnaea borealis* h.t.	grand fir/twinflower
593	-VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase
592	-XETE phase	-*Xerophyllum tenax* phase	-beargrass phase
591	-LIBO phase	-*Linnaea borealis* phase	-twinflower phase
580	ABGR/VACA h.t.	*Abies grandis/Vaccinium caespitosum* h.t.	grand fir/dwarf huckleberry
511	ABGR/COOC h.t.	*Abies grandis/Coptis occidentalis* h.t.	grand fir/western goldthread
520	ABGR/CLUN h.t.	*Abies grandis/Clintonia uniflora* h.t.	grand fir/queencup beadlily
600		*ABIES LASIOCARPA* SERIES	
605	ABLA/CABI h.t.	*Abies lasiocarpa/Caltha biflora* h.t.	subalpine fir/marsh marigold
650	ABLA/CACA h.t.	*Abies lasiocarpa/Calamagrostis canadensis* h.t.	subalpine fir/bluejoint
655	-LEGL phase	-*Ledum glandulosum* phase	-Labrador-tea phase
654	-VACA phase	-*Vaccinium caespitosum* phase	-dwarf huckleberry phase
652	-LICA phase	-*Ligusticum canbyi* phase	-Canby's ligusticum phase
651	-CACA phase	-*Calamagrostis canadensis* phase	-bluejoint phase
635	ABLA/STAM h.t.	*Abies lasiocarpa/Streptopus amplexifolius* h.t.	subalpine fir/twisted stalk
637	-LICA phase	-*Ligusticum canbyi* phase	-Canby's ligusticum phase
636	-STAM phase	-*Streptopus amplexifolius* phase	-twisted stalk phase
620	ABLA/CLUN h.t.	*Abies lasiocarpa/Clintonia uniflora* h.t.	subalpine fir/queencup beadlily
625	-MEFE phase	-*Menziesia ferruginea* phase	-menziesia phase
621	-CLUN phase	-*Clintonia uniflora* phase	-queencup beadlily
638	ABLA/COOC h.t.	*Abies lasiocarpa/Coptis occidentalis* h.t.	subalpine fir/western goldthread
670	ABLA/MEFE h.t.	*Abies lasiocarpa/Menziesia ferruginea* h.t.	subalpine fir/menziesia
672	-LUHI phase	-*Luzula hitchcockii* phase	-smooth woodrush phase
671	-MEFE phase	-*menziesia ferruginea* phase	-Menziesia phase
645	ABLA/ACGL h.t.	*Abies lasiocarpa/Acer glabrum* h.t.	subalpine fir/mountain maple
640	ABLA/VACA h.t.	*Abies lasiocarpa/Vaccinium caespitosum* h.t.	subalpine fir/dwarf huckleberry
660	ABLA/LIBO h.t.	*Abies lasiocarpa/Linnaea borealis* h.t.	subalpine fir/twinflower
661	-LIBO phase	-*Linnaea borealis* phase	-twinflower phase
662	-XETE phase	-*Xerophyllum tenax* phase	-beargrass phase
663	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
740	ABLA/ALSI h.t.	*Abies lasiocarpa/Alnus sinuata* h.t.	subalpine fir/Sitka alder
690	ABLA/XETE h.t.	*Abies lasiocarpa/Xerophyllum tenax* h.t.	subalpine fir/beargrass
691	-VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase
692	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
694	-LUHI phase	-*Luzula hitchcockii* phase	-smooth woodrush phase
720	ABLA/VAGL h.t.	*Abies lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry
723	-VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase
721	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
705	ABLA/SPBE h.t.	*Abies lasiocarpa/Spiraea betulifolia* h.t.	subalpine fir/white spirea
830	ABLA/LUHI h.t.	*Abies lasiocarpa/Luzula hitchcockii* h.t.	subalpine fir/smooth woodrush
831	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
833	-LUHI phase	-*Luzula hitchcockii* phase	-smooth woodrush phase
730	ABLA/VASC h.t.	*Abies lasiocarpa/Vaccinium scoparium* h.t.	subalpine fir/grouse whortleberry
731	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase
732	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
734	-PIAL phase	-*Pinus albicaulis* phase	-whitebark phase
750	ABLA/CARU h.t.	*Abies lasiocarpa/Calamagrostis rubescens* h.t.	subalpine fir/pinegrass h.t.
790	ABLA/CAGE h.t.	*Abies lasiocarpa/Carex geyeri* h.t.	subalpine fir/elk sedge h.t.
791	-CAGE phase	-*Carex geyeri* phase	-elk sedge phase
793	-ARTR phase	-*Artemisia tridentata* phase	-big sagebrush phase

(co

PPENDIX A. (Con.)

DP de[1]	Abbreviation		Scientific name	Common name
			ABIES LASIOCARPA SERIES (con.)	
45	ABLA/JUCO	h.t.	*Abies lasiocarpa/Juniperus communis* h.t.	subalpine fir/common juniper
10	ABLA/RIMO	h.t.	*Abies lasiocarpa/Ribes montigenum* h.t.	subalpine fir/mountain gooseberry
30	ABLA/ARCO	h.t.	*Abies lasiocarpa/Arnica cordifolia* h.t.	subalpine fir/heartleaf arnica
50	PIAL-ABLA	h.t.'s	*Pinus albicaulis-Abies lasiocarpa* h.t.'s	whitebark pine-subalpine fir
70			*PINUS ALBICAULIS* SERIES	
70	PIAL	h.t.'s	*Pinus albicaulis* h.t.'s	whitebark pine
00			*PINUS CONTORTA SERIES*	
20	PICO/VACA	c.t.	*Pinus contorta/Vaccinium caespitosum* c.t.	lodgepole pine/dwarf huckleberry
40	PICO/VASC	c.t.	*Pinus contorta/Vaccinium scoparium* c.t.	lodgepole pine/grouse whortleberry
50	PICO/CAGE	c.t.	*Pinus contorta/Carex geyeri* c.t.	lodgepole pine/elk sedge
05	PICO/FEID	h.t.	*Pinus contorta/Festuca idahoensis* h.t.	lodgepole pine/Idaho fescue

Automatic data processing codes.

APPENDIX B: OCCURRENCE AND ROLES OF TREE SPECIES BY HABITAT TYP

Occurrence of tree species through the series of habitat types, showing their status in forest succession as interpreted from central Idaho reconnaissance plot data (Steele and others 1981).

C = major climax species
c = minor climax species
S = major seral species
s = minor seral species
a = accidental
( ) = only in certain areas of h.t.

Habitat type-phase	JUSC	POTR	PIFL	PIPO	PSME	PICO	PIEN	LAOC	ABGR	ABLA	PIA
PIFL/FEID	(c)	–	C	–	C	–	–	–	–	–	–
PIPO/STOC	–	–	–	C	–	–	–	–	–	–	–
PIPO/AGSP	–	–	–	C	a	–	–	–	–	–	–
PIPO/FEID	–	a	–	C	a	–	–	–	–	–	–
PIPO/PUTR, AGSP	–	a	–	C	a	–	–	–	–	–	–
PIPO/PUTR, FEID	–	–	–	C	a	–	–	–	–	–	–
PIPO/SYOR	–	–	–	C	a	–	–	–	–	–	–
PIPO/SYAL	–	(s)	–	C	a	–	–	–	–	–	–
PSME/AGSP	–	a	–	(C)	C	–	–	–	–	–	–
PSME/FEID, FEID	–	–	–	–	C	a	–	–	–	–	–
PSME/FEID, PIPO	–	–	–	C	C	a	–	–	–	–	–
PSME/SYOR	–	a	(c)	(c)	C	a	–	–	–	–	–
PSME/ARCO, ASMI	a	–	s	–	C	–	a	–	–	–	–
PSME/ARCO, ARCO	–	a	(s)	–	C	(s)	a	–	–	a	a
PSME/JUCO	–	–	(s)	–	C	(s)	–	–	–	a	a
PSME/CAGE, SYOR	–	a	a	–	C	(s)	–	–	–	a	a
PSME/CAGE, PIPO	–	–	–	S	C	a	–	–	–	–	–
PSME/CAGE, CAGE	–	a	a	–	C	(s)	–	–	–	a	a
PSME/BERE, SYOR	–	–	–	(c)	C	–	–	–	–	–	–
PSME/BERE, CAGE	–	–	–	S	C	–	–	–	–	–	–
PSME/CAGE, BERE	–	–	–	(S)	C	(c)	–	–	–	–	–
PSME/CELE	–	–	(c)	(C)	C	a	–	–	–	–	–
PSME/CARU, FEID	–	–	–	–	C	–	–	–	–	–	–
PSME/CARU, PIPO	–	–	–	S	C	(S)	–	–	–	–	–
PSME/CARU, CARU	–	s	–	–	C	(S)	a	–	–	a	a
PSME/OSCH	–	–	–	(S)	C	–	–	–	–	a	a
PSME/SPBE, PIPO	–	a	–	S	C	a	a	–	–	a	a
PSME/SPBE, CARU	–	–	–	–	C	(S)	–	–	–	–	–
PSME/SPBE, SPBE	–	–	a	–	C	(s)	–	–	–	a	a
PSME/SYAL, PIPO	–	(s)	–	S	C	(s)	–	–	–	–	–
PSME/SYAL, SYAL	–	a	–	–	C	a	–	–	–	a	a
PSME/ACGL, SYOR	s	–	s	–	C	–	–	–	–	–	–
PSME/ACGL, ACGL	–	(S)	–	(S)	C	–	–	–	–	a	a
PSME/PHMA, PIPO	–	–	–	S	C	–	–	–	–	a	-
PSME/PHMA, PSME	–	–	–	–	C	–	–	–	–	–	-
PIEN/HYRE	–	–	S	–	C	–	C	–	–	–	-
PIEN/CADI	–	a	–	–	a	S	C	–	–	c	-
ABGR/CARU	–	–	–	S	S	(S)	a	–	C	a	a
ABGR/SPBE	–	(s)	–	S	S	–	a	a	C	–	-
ABGR/VAGL	–	a	–	s	S	s	S	(s)	C	(c)	-
ABGR/ACGL, PHMA	–	–	–	S	S	–	a	a	C	(c)	-
ABGR/ACGL, ACGL	–	–	–	S	S	–	a	a	C	(c)	-
ABGR/LIBO, VAGL	–	–	–	s	S	s	s	(s)	C	(c)	-
ABGR/LIBO, LIBO	–	–	–	S	S	s	a	a	C	–	-
ABGR/VACA	–	–	–	(s)	(S)	S	s	s	C	c	-
ABGR/CLUN	–	–	–	s	s	(s)	S	S	C	(c)	-
ABLA/CABI	–	a	–	–	–	a	S	–	–	C	-
ABLA/CACA, LEGL	–	–	–	–	s	S	S	–	a	C	-
ABLA/STAM, LICA	–	–	–	–	a	s	S	–	a	C	-
ABLA/STAM, STAM	–	–	–	–	a	s	S	–	–	C	-

(c

PPENDIX B. (Con.)

Habitat type-phase	JUSC	POTR	PIFL	PIPO	PSME	PICO	PIEN	LAOC	ABGR	ABLA	PIAL
LA/CLUN, CLUN	–	–	–	a	S	s	S	(S)	(c)	C	–
LA/MEFE, MEFE	–	–	–	–	s	(S)	S	(S)	(c)	C	–
LA/ACGL	–	a	–	–	S	–	–	–	–	C	–
LA/VACA	–	a	–	–	s	S	s	–	a	C	s
LA/LIBO, LIBO	–	–	–	–	S	S	S	–	a	C	a
LA/XETE, VAGL	–	–	–	–	(S)	S	S	–	–	C	–
LA/XETE, VASC	–	–	–	–	(S)	S	s	–	–	C	(s)
LA/XETE, LUHI	–	–	–	–	–	(s)	(S)	–	–	C	s
LA/VAGL, VAGL	–	–	–	a	S	a	S	–	a	C	a
LA/SPBE	–	–	–	a	S	(S)	a	–	–	C	a
LA/LUHI, VASC	–	–	–	–	–	S	s	–	–	C	s
LA/LUHI, LUHI	–	–	–	–	–	s	s	–	–	C	s
LA/VASC, CARU	–	–	–	–	s	S	s	–	–	C	–
LA/VASC, VASC	–	–	–	–	a	S	s	–	–	C	s
LA/VASC, PIAL	–	–	–	–	–	(S)	a	–	–	C	C
LA/CARU	–	–	–	–	S	S	–	–	a	C	s
LA/CAGE, CAGE	–	a	–	–	(S)	(S)	(s)	–	–	C	s
LA/CAGE, ARTR	–	–	–	–	(s)	a	–	–	–	C	c
LA/JUCO	–	–	–	–	(S)	(S)	s	–	–	C	s
LA/RIMO	–	–	–	–	a	–	(s)	–	–	C	S
LA/ARCO	–	–	–	–	s	(S)	S	–	–	C	s
L/ABLA	–	–	–	–	–	(s)	a	–	–	C	C
O/FEID	–	–	–	–	–	C	–	–	–	–	(c)

APPENDIX C: SCIENTIFIC NAMES OF PLANTS MENTIONED IN TEXT

Common name	Scientific name
alder	*Alnus* spp.
alpine knotweed	*Polygonum phytolaccaefolium*
antelope bitterbrush	*Purshia tridentata*
arrowleaf balsamroot	*Balsamorhiza sagittata*
arrowleaf groundsel	*Senecio triangularis*
aspen	*Populus tremuloides*
baldhip rose	*Rosa gymnocarpa*
ballhead sandwort	*Arenaria congesta*
bearberry	*Arctostaphylos uva-ursi*
beargrass	*Xerophyllum tenax*
bigleaf sandwort	*Arenaria macrophylla*
big sagebrush	*Artemisia tridentata*
birch	*Betula* spp.
bitterbrush	*Purshia tridentata*
blue huckleberry	*Vaccinium globulare*
bluebunch wheatgrass	*Agropyron spicatum*
bluejoint	*Calamagrostis canadensis*
bracted pedicularis	*Pedicularis bracteosa*
broadleaf arnica	*Arnica latifolia*
brook saxifrage	*Saxifraga arguta*
Canby's ligusticum	*Ligusticum canbyi*
chokecherry	*Prunus virginiana*
coiled lousewort	*Pedicularis contorta*
Columbia clematis	*Clematis columbiana*
Columbian monkshood	*Aconitum columbianum*
common horsetail	*Equisetum arvense*
common juniper	*Juniperus communis*
common snowberry	*Symphoricarpos albus*
cottonwood	*Populus* spp.
creeping barberry	*Berberis repens*
creeping Oregon grape	*Berberis repens*
curlleaf mountain-mahogany	*Cercocarpus ledifolius*
currant	*Ribes* spp.
dampwoods blueberry	*Vaccinium globulare*
darkwoods violet	*Viola orbiculata*
Douglas-fir	*Pseudotsuga menziesii*
dwarf huckleberry	*Vaccinium caespitosum*
elk sedge	*Carex geyeri*
Engelmann spruce	*Picea engelmannii*
fairybells	*Disporum trachycarpum*
false bugbane	*Trautvetteria caroliniensis*
false-hellebore	*Veratrum viride*
false Solomon's seal	*Smilacina racemosa*
firestamen miterwort	*Mitella pentandra*
fireweed	*Epilobium angustifolium*
grand fir	*Abies grandis*
grouse whortleberry	*Vaccinium scoparium*
hawthorn	*Crataegus* spp.
heartleaf arnica	*Arnica cordifolia*
Hook violet	*Viola adunca*
Hooker fairybells	*Disporum hookeri*
honeysuckle	*Lonicera caerulea*
hypnum	*Hypnum revolutum*
Idaho fescue	*Festuca idahoensis*
Indian poke	*Veratrum viride*
junegrass	*Koeleria cristata*
kinnikinnick	*Arctostaphylos uva-ursi*
Labrador-tea	*Ledum glandulosum*
larch	*Larix occidentalis*
limber pine	*Pinus flexilis*
lodgepole pine	*Pinus contorta*
marsh marigold	*Caltha biflora*
menziesia	*Menziesia ferruginea*
mountain arnica	*Arnica latifolia*
mountain ash	*Sorbus scopulina*
mountain big sagebrush	*Artemisia tridentata* ssp. *vaseyana*
mountain gooseberry	*Ribes montigenum*
mountain-mahogany	*Cercocarpus ledifolius*
mountain maple	*Acer glabrum*
mountain snowberry	*Symphoricarpos oreophilus*
mountain sweet-root	*Osmorhiza chilensis*
myrtle pachistima	*Pachistima myrsinites*
Nevada peavine	*Lathyrus nevadensis*
ninebark	*Physocarpus malvaceus*
oceanspray	*Holodiscus discolor*
oniongrass	*Melica bulbosa*
pathfinder	*Adenocaulon bicolor*
Parry rush	*Juncus parryi*
pinegrass	*Calamagrostis rubescens*
Piper's anemone	*Anemone piperi*
pokeweed fleeceflower	*Polygonum phytolaccaefolium*
ponderosa pine	*Pinus ponderosa*
prickly currant	*Ribes lacustre*
pussytoes	*Antennaria racemosa*
pyramid spirea	*Spiraea pyramidata*
quaking aspen	*Populus tremuloides*
queencup beadlily	*Clintonia uniflora*
red baneberry	*Actaea rubra*
Richardson geranium	*Geranium richardsonii*
Rocky Mountain maple	*Acer glabrum*
rose	*Rosa* spp.
Ross sedge	*Carex rossii*
rosy pussytoes	*Antennaria macrophylla*
russet buffaloberry	*Shepherdia canadensis*
Scouler willow	*Salix scoulerana*
sedge	*Carex* spp.
serviceberry	*Amelanchier alnifolia*
shooting star	*Dodecatheon jeffreyi*
showy aster	*Aster conspicuus*
shrubby cinquefoil	*Potentilla fruticosa*
sidebells pyrola	*Pyrola secunda*
silvery lupine	*Lupinus argenteus*
Sitka alder	*Alnus sinuata*
Sitka valerian	*Valeriana sitchensis*
smooth woodrush	*Luzula hitchcockii*
snowberry	*Symphoricarpos* spp.
snowbrush ceanothus	*Ceanothus velutinus*
snowlover	*Chionophila tweedyi*
soft-leaved sedge	*Carex disperma*
spikefescue	*Hesperochloa kingii*
spreading sweet-root	*Osmorhiza chilensis*
spruce	*Picea engelmannii*
starry Solomon-plume	*Smilacina stellata*
starry Solomon's seal	*Smilacina stellata*
sticky geranium	*Geranium viscosissimum*
strawberry	*Fragaria* spp.
subalpine fir	*Abies lasiocarpa*
sweetscented bedstraw	*Galium triflorum*
thimbleberry	*Rubus parviflorus*
Thurber fescue	*Festuca thurberi*
twinflower	*Linnaea borealis*
twisted stalk	*Streptopus amplexifolius*
Utah honeysuckle	*Lonicera utahensis*
wax currant	*Ribes cereum*
weedy milkvetch	*Astragalus miser*
western goldthread	*Coptis occidentalis*
western larch	*Larix occidentalis*
western meadowrue	*Thalictrum occidentale*
western needlegrass	*Stipa occidentalis*
western pipsissewa	*Chimaphila umbellata*
Wheeler bluegrass	*Poa nervosa*
white spirea	*Spiraea betulifolia*
whitebark pine	*Pinus albicaulis*
Wilcox's penstemon	*Penstemon wilcoxii*
wild strawberry	*Fragaria* spp.
willow	*Salix* spp.
woodrush	*Luzula hitchcockii*
Woods rose	*Rosa woodsii*
Yarrow	*Achillea millefolium*

☆U.S. GOVERNMENT PRINTING OFFICE:1986—773-039/41029

Crane, M. F.; Fischer, William C. Fire ecology of the forest habitat types of central Idaho. General Technical Report INT-218. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 86 p.

Discusses fire as an ecological factor for forest habitat types occurring in central Idaho. Identifies "Fire Groups" of habitat types based on fire's role in forest succession. Considerations for fire management are suggested.

KEYWORDS: fire ecology, forest ecology, forest fire, fire management, habitat types

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

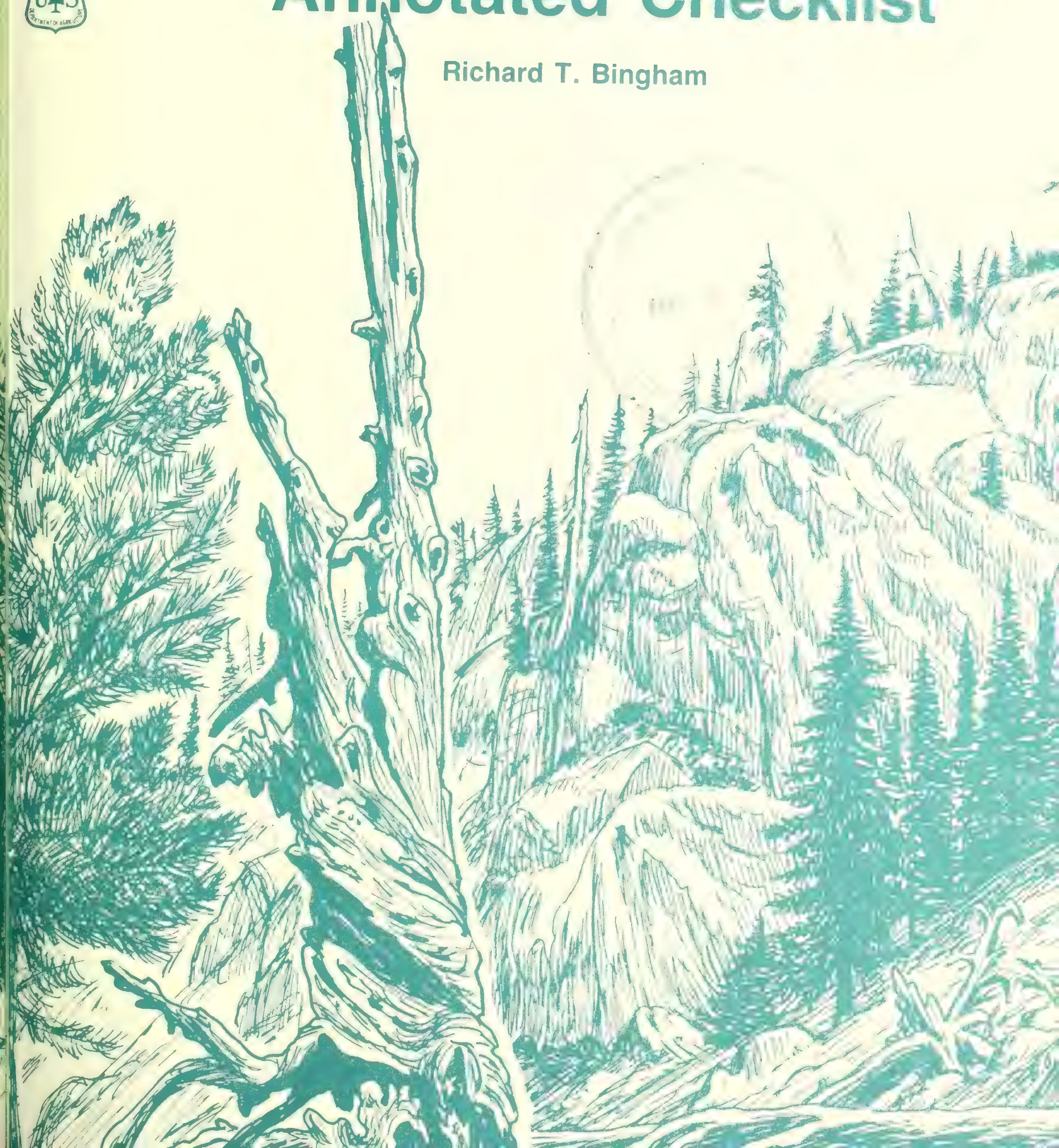
Forest Service

**Intermountain
Research Station**

General Technical
Report INT-219

Plants of the Seven Devils Mountains of Idaho—An Annotated Checklist

Richard T. Bingham



THE AUTHOR

RICHARD T. (DICK) BINGHAM retired from the Intermountain Station in 1974, after 34 years with the Forest Service. The greater part of his research career was spent leading a successful, 25-year program of breeding for blister rust resistance in western white pine. This work is summed up in his General Technical Report INT-146, "Blister Rust Resistant Western White Pine for the Inland Empire," 1978, and in American Forests, December 1984, "New Beginning for the Western White Pine," by Louise Kingsbury. Since retirement, Dick has continued to work as a Forest Service volunteer, both for the Intermountain Station and the Hells Canyon National Recreation Area. In this capacity, he has coauthored two local plant floras written for the NRA—with D. M. Henderson of the University of Idaho, a "Guide to the Common Plants of Hells Canyon" (1978), and with C. J. Miller, Forest Service volunteer from St. Maries, ID, a "Guide to the Common Plants of the Seven Devils Mountains" (in press).

RESEARCH SUMMARY

The author has assembled a checklist of 722 plant taxa found above 5,000 ft elevation in the Seven Devils Mountains and along the Wild River Corridor of the Rapid River of west-central Idaho. This list is based on the author's and Clyde J. Miller's field work and on data compiled from the labels of specimens of seven regional herbaria, altogether representing 45 individuals who collected plants in the Seven Devils Mountains between 1899 and 1984. The checklist rates taxa for frequency of occurence and general geographic and elevational distribution.

The checklist includes annotations for almost 2,700 plant collections from the Seven Devils and deposited in seven Inland Northwest herbaria (BKR, BOIS, Council R.D., ID, IDF, OGDF, and WS; see text, table 2). Each plant collection cited is accompanied by the following annotations: collector's name, his or her accession number, herbarium of deposition, specific locality and elevational data, and habitat information where available from the herbarium label.

The checklist will be of interest to vegetation managers and researchers, including systematic botanists, forest ecologists, silviculturists, range conservationists, and those who monitor rare plants.

March 1987
Intermountain Research Station
324 25th Street
Ogden, UT 84401

CONTENTS

Page
Introduction 1
Checklist Format 6
Geological History and Geology of the Seven Devils Mountains 11
Botanical History of the Seven Devils Mountains . . . 12
References 16
Checklist 18
Aceraceae 18
Anacardiaceae 18
Apiaceae 18
Apocynaceae 22
Asclepiadaceae 22
Asteraceae 22
Berberidaceae 41
Betulaceae 41
Boraginaceae 42
Brassicaceae 44
Campanulaceae 49
Caprifoliaceae 49
Caryophyllaceae 51
Celastraceae 55
Chenopodiaceae 55
Convolvulaceae 55
Cornaceae 55
Crassulaceae 55
Cupressaceae 56
Cyperaceae 57
Dipsacaceae 60
Elaeagnaceae 60
Equisetaceae 60
Ericaceae 60
Fabaceae 64
Fumariaceae 69
Gentianaceae 69
Geraniaceae 71
Grossulariaceae 71
Hydrangeaceae 74
Hydrophyllaceae 74
Page
Hypericaceae 76
Iridaceae 76
Isoetaceae 77
Juncaceae 77
Lamiaceae 78
Liliaceae 79
Limnanthaceae 84
Linaceae 84
Loasaceae 85
Malvaceae 85
Nymphaceae 85
Onagraceae 86
Orchidaceae 88
Orobanchaceae 90
Paeoniaceae 91
Pinaceae 91
Plantaginaceae 92
Poaceae 93
Polemoniaceae 102
Polygonaceae 105
Polypodiaceae 109
Polytrichaceae 112
Portulacaceae 112
Potomogetaceae 114
Primulaceae 114
Ranunculaceae 115
Rhamnaceae 120
Rosaceae 120
Rubiaceae 127
Salicaceae 128
Saxifragaceae 129
Scrophulariaceae 132
Selaginaceae 143
Sparganiaceae 143
Sphagnaceae 143
Taxaceae 143
Ulmaceae 143
Urticaceae 143
Valerianaceae 144
Violaceae 144

Plants of the Seven Devils Mountains of Idaho—An Annotated Checklist

Richard T. Bingham

INTRODUCTION

During the summers from 1977 through 1983, the author and fellow Forest Service volunteer Clyde J. Miller (formerly of the St. Joe National Forest) traveled most of the trails and roads of west-central Idaho's Seven Devils Mountains—observing, collecting, and identifying the plants found there. The first objective of this pleasant work has been to produce a layman's guide to the common plants of these scenic, wilderness mountains, and this goal is largely in hand, with the completion of the manuscript "Guide to the Common Plants of the Seven Devils Mountains," submitted to the Hells Canyon National Recreation Area in February 1983. A second objective has been to provide a solid foundation—this checklist—toward a technical and complete flora of the Seven Devils Mountains.

For purposes of this checklist, the Seven Devils Mountains include those forest and grass lands lying above 5,000 ft elevation along the divide between the Snake River on the west and the Salmon, Little Salmon, or Weiser rivers on the east, from Camp Howard (5 mi southwest of White Bird, ID, lat. 45° 43′ N.) on the north, to Sheep Peak, also known as Sheep Mountain, on the south but not Sheep Rock (5 mi south-southeast of the Snake River Oxbow and 1½ mi northwest of the Wildhorse River, lat. 44° 54′ N.). (See Nez Perce National Forest map.) More specifically, proceeding southward and clockwise from Camp Howard Cow Camp along its east side, the study area is defined by Big Canyon Saddle, Grave Point, Cow Creek Saddle, Buckhorn Spring, Papoose Saddle, Aitken Spring, Rattlesnake Spring, Lockwood Point, Campbell Cow Camp, Pollock Mountain, Ant Butte, Lick Creek Lookout, Huckleberry Camp, heads of Grouse and Fawn Creeks, and the divides between Bear and Indian Creeks, then the Wildhorse and Snake Rivers to Sheep Peak (or Sheep Mountain) on the south. Then going north along its west side, the study area is defined by Horse Mountain, Lockwood Saddle, Kinney Point, Sheep Rock, Cliff Mountain, Granite Mountain, the west side of Potato Hill, Timbered Bench, Three Creek Point, Dry Diggins Lookout, McGaffee Cow Camp, Low Saddle, Sawpit Saddle, Forest Service road 2060, Kirkwood Corrals, Dixon Corrals, and Wild Horse Butte back to Camp Howard.

This often narrow strip of extremely rough and broken country runs for about 60 mi north and south but averages less than 5 mi wide east and west (from less than 1 mi to more than 13 mi). Most of it lies within the Hells Canyon Wilderness of the Hells Canyon National Recreation Area, while perhaps a third of it, on the north, east, and south, falls in the Slate-Salmon Ranger District of the Nez Perce National Forest or in the Council Ranger District of the Payette National Forest. Also included is the Rapid River Wild River Corridor, running between 2,200 and 7,400 ft in elevation, upstream from the Circle C State Fish Hatchery. Most of the typically low-elevation plant taxa in the checklist were found along trail 113 in the lower Rapid River Corridor. Probably fewer than 5 mi^2 of private lands are included—patented mining claims or high grazing lands, the latter almost exclusively on the south.

This checklist includes 722 plant taxa, 293 genera, and 71 families, represented by 2,700 different, mounted herbarium collections and 5,470 sight records made by experienced observers. The checklist has been assembled over 4 years, as follows:

1. A core list of about 535 taxa was developed using the field collection notes of four contemporary collectors, or parties of collectors. The list included 500 taxa from the 620 collections and 3,600 sight records of Bingham and Miller, and 35 additional taxa from the 74 collections and 123 sight records of D. M. Henderson, E. W. Tisdale, and C. A. Wellner (see table 1 for more information on these collectors).
2. The 535-taxon list then was checked through the three local herbaria (the University of Idaho Herbarium, acronym ID; the University of Idaho College of Forestry, Wildlife and

Table 1—Seven Devils Mountains plant collectors with notes on their places of work and affiliated herbaria, date, locality and number of their plant collections, and on their field collection records

---

Legend:

(A) Name of collector(s) (if underlined, deceased)

(B) Years collected

(C) Affiliated herbaria

(D) Place of work when collections were made

(E) Description and disposition of any field collection records

(F) Localities where collections were made (see Nezperce and Payette N.F. maps)

(G) Number of collections: G1 = Number seen,
G2 = Approximate total number

(A) Aase, Hannah C. (B) 1940 (C) WS (D) Botany Department, Washington State University, Pullman (E) Collections dated, not numbered, no records found at WSU botany department or library archives (F) Vicinity of Heavens Gate Lookout (G1) 1 (G2) 1^+

(A) Aldrich, John (B) 1907 (C) ID (D) Entomology Department, University of Idaho, Moscow (E) Collections dated, not numbered, no records found at ID or university (F) Camp Howard (probably the Cow Camp) (G1) 14 (G2) 14^+

(A) Baird, Dan (B) 1971-72 (C) Council R.D. (D) Council Ranger District, Payette National Forest, Council, ID (E) No notes found at Council but complete herbarium search made there (F) Rds. 108 and 106 Horse Mountain to Sheep Rock, rd. 105 Bear Guard Station to Cuprum, rd. 002 Summit Creek and Huntley Gulch to top of Kleinschmidt Grade, rd. 112 Placer Basin to Black Lake, trail 214 Black Lake to Horse Heaven Lookout, and trail 227 Helena to head of Camp Creek (G1) 52 (G2) 52^+

(A) Baker, William H. (B) 1953, 1954, 1955 (C) ID (D) Herbarium, University of Idaho, Department of Biological Sciences, (E) Collection notebooks at ID (F) rd. 106 to Sheep Rock; Rd. 517 in Papoose and Shingle Creeks; Windy Saddle to Heavens Gate L.O.; Seven Devils Gd. Station; White Bird Ridge and lower Rapid River (G1) 196 (G2) 219

(A) Bingham, Richard T. and Miller, Clyde J. (B) 1977-83 (C) ID, IDF, WS (D) Intermountain Researc Station, USFS, Moscow, ID (E) Records at Bingham's home (bequeathed to ID), Seven Devils trail and road plant surveys produced 3,592 sight records (F) All of Seven Devils except extrem south (Sheep Peak) or east (Pollock Mountain plus White Bird Ridge to Lick Creek L.O.) (G1) 620 (G2) 620

(A) Brewer, Vernon M. (B) 1928-31 (C) IDF, Council R.D. (D) Bear Ranger District, Weiser (now Guard Station, Payette) National Forest (E) 95 of 142 collections found in IDF or Council R.D. herbaria, but no records there (F) Rds. 106 to Helena and 112 to Black Lake; trails 190, 191, 217 and 219; Sheep Peak or Mountain; heads of Summit Gulch and Boulder Creek (G1) 47 (G2) 100^-

(A) Burkhardt, J. Wayne (B) 1968 (C) IDF (D) College of Forestry, University of Idaho, Moscow (E) N records found, correspondence unanswered (F) Kleinschmidt Grade; 5,000 ft (G1) 1 (G2) 1^+

(A) Christ, John H. (B) 1937, 1940, 1941 (C) ID, NY, WS (D) Idaho Agric. Exp. Stn., Sandpoint, ID and Soil Conservation Service, Portland, OR (E) Collection ledgers at ID, main collection at NY (F) Black Lake, Pyramid Peak, vicinity Cuprum, Seven Devils Lake, Windy Saddle, Heavens Gate L.O., trail 112 Windy Saddle to Hibbs Cow Camp, 123 to Lily Pad Lake, "Sheep Creek Swamp," and Sheep Lake, and 124 to Baldy Lake (G1) 115 (G2) 435

(A) Comstock, Verne E. (B) 1939 (C) WS (D) Agronomy Department, Washington State University, Pullman (E) Records lost, teste Comstock (F) Lightning Creek (off Sheep Creek), ? trails 52 or (G1) 6 (G2) 10

(A) Cusick, William C. (B) 1899 (C) GH, WS, ORE (D) Self-employed farmer and plant collector with farm near Union, OR (E) Supposedly at ORE, but 1899 records missing, teste D. H. Wagner, curator (F) Kleinschmidt Grade from Snake River to Old Helena and Peacock Mines (G1) 7 (G2) 8^+

(A) Davis, Ray J. (B) 1940 (C) IDF, IDS, WS (D) Idaho State University, Pocatello (E) Records discarded in 1982, teste his son, H. W. Davis (F) Grave Point, Heavens Gate, trails 112 and 5 to Dry Diggins L.O. and Bernard Lakes (G1) 43 (G2) 154^-

(A) Gentry, Johnnie L. and Davidse, Gerrit (B) 1967 (C) F, ID (D) Field Museum of National History, Chicago, IL (E) No reply to two inquiries (F) Rd. 517 east of Heavens Gate L.O. (G1) 1 (G2) 1^+

(A) Henderson, Douglass M. (B) 1977 (C) ID (D) University of Idaho Herbarium, Department of Biological Sciences, Moscow (E) Records obtained from Henderson at ID (F) Goat Pass manw to Sheep Lake, trail 123 Sheep Lake to trail 112, trail 112 Hibbs Cow Camp to Windy Saddle (G1) 19 (G2) 19

(c

Table 1. (Con.)

(A) Hermann, Frederick J. (B) 1955 (C) MICH, NA, RM, US, WS (D) Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO (E) Field records photocopied and sent by MICH (F) Cold Springs L.O., Shingle Creek along road 517, Heavens Gate L.O. (G1) 18 (G2) 18

(A) Hibbs, Esther C. (Mrs. Earl E. Hibbs) (B) 1937 (C) WS (D) Department of Fine Arts, Washington State University, Pullman (E) Collections dated, not numbered, no records kept, teste Hibbs (F) Dry Diggins area, Hibbs Cow Camp, "The Swamps" (G1) 6 (G2) 6^{+}

(A) Holmgren, Arthur H., and Tillett, Stephen S. (B) 1953, 1954 (C) UTC, WS (D) Intermountain Herbarium, Biology Department, Utah State University, Logan (E) No reply to two inquiries (F) Kleinschmidt Grade, vicinity of Cuprum, and Kinney Point (G1) 5 (G2) 8^{+}

(A) Howell, L. (B) 1974 (C) ID (D) Unknown (probably University of Idaho student) (E) Unable to locate (F) 6 mi up Rapid River (G1) 1 (G2) 1^{+}

(A) Johnson, Charles G., Jr. (B) 1982-84 (C) BKR, ID, WS (D) Wallowa-Whitman National Forest, Baker, OR (E) Records for fifteen 1982 and seventy-seven 1983 recon. plots, included 1,550 sight records, sent by Johnson; list of collections, dated only but mostly identified by BKR Herbarium numbers (F) All of Seven Devils except extreme south (Sheep Peak), southwest (rd. 106 to Kinney Point and Sheep Rock), and east (Pollock Mountain to Lick Creek L.O.) (G1) 74 (G2) 74

(A) Johnson, E. C. (B) 1931 (C) Unknown (D) Unknown (E) Single collection cited by Hitchcock and others, Part 2, p. 131, 1964 (F) Rds. 105 and 112, Black Lake to Bear P.O. (G1) 1 (G2) 1^{+}

(A) Johnson, Frederic D. (B) 1962, 1964, 1968 (C) IDF (D) College of Forestry, University of Idaho, Moscow (E) Collections dated, not numbered, no other collections recalled, teste Johnson (F) Heavens Gate, Cow Creek Saddle, Pittsburg Saddle (G1) 5 (G2) 5^{+}

(A) Jones, Marcus E. (B) 1899 (C) RSA (D) Consulting geologist to Pacific and Idaho Northern R.R. and commercial plant collector (E) Presumably no records exist since these kept only late in Jones' life, teste L. W. Lenz, Director, RSA. A single collection is cited by Hitchcock and others, Part 3, p. 327, 1961 (F) Southern Seven Devils (probably near Cuprum) (G1) 1 (G2) 1^{+}

(A) Jones, Quentin (B) 1950 (C) ID, WS (D) Botany Department, Washington State University, Pullman (E) 1950 records lost, teste Jones (F) Heavens Gate L.O. and rd. 517 near Shingle Creek (G1) 36 (G2) 40^{+}

(A) Kruckeberg, Arthur R. (B) 1951, 1952 (C) WTU, WS, etc. (D) Botany Department, University of Washington, Seattle (E) 1951 records missing (4^{+} collections), teste Kruckeberg, but 1952 records photocopied and sent by Kruckeberg (F) Windy Saddle, Seven Devils Guard Station, trail 112 and 56 to Dry Diggins L.O., trail 123 to Shelf Lake (G1) 36 (G2) 38^{+}

(A) LaZelle, Monta C. (B) 1963 (C) ID (D) University of Idaho, herbarium, Department of Biological Sciences, Moscow (E) No records kept, teste LaZelle (F) Seven Devils Campground, Lake, and Gd. Station (G1) 17 (G2) $22^{\pm}$

(A) Lewis, Mont E. (B) 1972 (C) BOIS (D) Retired, division range management, U.S. Forest Service, Ogden, UT (E) Lewis can't find 1972 records but 1967 records found (F) Rd. 105 and 108 and rd. 002 at Bear-Cuprum Creeks divide north of Cuprum (G1) 26 (G2) 30^{+}

(A) McDowell, W. A. (B) 1926 (C) Council R.D. (D) Hornet Ranger District, Weiser National Forest (now Hornet Guard Station, Payette National Forest) Council, ID (E) No notes found at Council but complete herbarium search made there (F) Placer Creek (fork of Indian Creek) (G1) 1 (G2) 1^{+}

(A) Meyer, Frederick G. (B) 1936, 1937, 1939 (C) WS (D) Botany Department, Washington State University, Pullman (E) No reply to two inquiries (F) Ridges above lower Sheep Creek, McGaffee Cow Camp, "Seven Devils Mountains" (G1) 10 (G2) $19^{\pm}$

(A) Moore, William R. (B) 1936 (C) WS (D) Department of Forestry, Washington State University, Pullman (E) Original field notes sent by Moore (F) Bernard Creek, McGaffee Cow Camp, ridge above McGaffee Cow Camp (G1) 20 (G2) 23

(A) Munro, Gerald W. (B) 1937 (C) WS (D) Horticulture Department, Washington State University, Pullman (E) No reply to two inquiries (F) "Foot of Seven Devils Mountains," McGaffee Cow Camp, and ridge north of McGaffee Cow Camp (G1) 10 (G2) 12^{+}

(A) Nelson, Aven, and Nelson, Ruth A. (B) 1938 (C) RM, WS (D) Rocky Mountain Herbarium, University of Wyoming, Laramie (E) Records photocopied and sent by RM, 16 of 65 collections verified as there and nearly all believed there, teste B. E. Nelson, herbarium manager (F) "Rapid River trail," summit He Devil Mountain, Dry Diggins Area, Dry Diggins "Ranger Station or Camp," Horse Heaven, "Silver Springs trail" (G1) 18 (G2) 65

(con.)

Table 1. (Con.)

(A) Ownbey, Marion, and Meyer, Frederick G. (B) 1940 (C) WS (D) Botany Department, Washington State University, Pullman (E) Collection records photocopied at WSU Library Archives, four collections unidentified (F) Papoose Creek along rd. 517, trail 112 from Windy Saddle to Hibbs Cow Camp, vicinity of Heavens Gate (G1) 30 (G2) 35

(A) Packard, Jacqueline (Mrs. William R. Moore) (B) 1936-39 (C) WS (D) Botany Department, Washington State University, Pullman (E) 1937 field collection notebook and fragmentary 1936, 1938, 1939 records sent by Mrs. Moore (F) McGaffee Cow Camp, Little Granite Creek, trail 112, Hibbs Cow Camp, Dry Diggins Area, Lily Pad Lake, Basin, Shelf, Gem, and Sheep Lakes, "The Swamps," Stormy Point and Low Saddle (G1) 110 (G2) 123$^+$

(A) Pennell, Francis W. (B) 1937 (C) PH, WS (D) Philadelphia Academy of Natural Sciences, Philadelphia, PA (E) Collection records photocopied and sent by PH Archives, three collections verified by PH assistant curator A. E. Schuyler (F) "Mailbox Saddle," Smith Mountain, Black Lake (G1) 5 (G2) 30

(A) Peters, Don L. (B) 1936 (C) WS (D) College of Agriculture, Washington State University, Pullman (E) Search for records still proceeding (F) Vicinity McGaffee Cow Camp (G1) 3 (G2) 22$^\pm$

(A) Sharp, Lee A., and McKendrick, Jay D. (B) 1965 (C) IDF (D) Range Management Department, College of Forestry, University of Idaho, Moscow (E) Collections dated, not numbered, Sharp has no recollection of other collections (F) Heavens Gate Lookout (G1) 2 (G2) 2$^+$

(A) Sharsmith, Carl W. (B) 1939 (C) WS (D) Botany Department, Washington State University, Pullman (E) Collection records photocopied at WSU Library Archives (F) Rim of Snake River Canyon in Sheep Creek, ridge overlooking upper basin of Sheep Creek (G1) 2 (G2) 2

(A) Simon, Steven (B) 1984 (C) BKR (D) Wallowa-Whitman National Forest, Baker, OR (E) All Seven Devils collections seen at BKR (F) Horse Heaven Lookout and vicinity of Haas Lake (G1) 4 (G2) 4

(A) Spellenberg, Richard, and Spellenberg, Marie (B) 1967 (C) ID, WS, WTU (D) Botany Department, University of Washington, Seattle (E) Photocopies of records sent by Spellenberg (F) Rd. 106, 5 mi north of Cuprum to Kinney Point (G1) 1 (G2) 2

(A) St. John, Harold, and Mullen, Lowell A. (B) 1927 (C) WS (D) Botany Department, Washington State University, Pullman (E) Photocopies of field collection records sent by St. John (F) Lime Saddle, The Narrows, trail 110 from Papoose Creek to McGaffee Cow Camp, Bernard Creek, trail 140 from McGaffee Cow Camp to trail 112, Dry Diggins, Lily Pad Lake, head of the Echo Lake fork of Little Granite Creek, He Devil Mountain (G1) 159 (G2) 176

(A) Steele, Robert (B) 1972, 1974, 1981 (C) BOIS, ID, IDF (D) Intermountain Research Station, Boise, ID (E) Photocopies of seven BOIS labels sent by Steele, also of 203 sight records from seven plots, all known Seven Devils taxa searched for at BOIS by author (F) Rd. 517 below the south fork of Papoose Creek, Heavens Gate, Cuprum rds. 105 and 002, and heads of Fawn Creek an Grouse Creek along rd. 127 (G1) 14 (G2) 14$^+$

(A) Taylor, Ronald J. (B) 1967 (C) WWB (D) Department of Biology, Western Washington University, Bellingham (E) List of collections sent by Taylor (F) Vicinities of Shelf, Gem, and Sheep Lakes (G1) 8 (G2) 8

(A) Tisdale, Edwin W. (B) 1978, 1979 (C) IDF (D) Department of Range Management, College of Forestry, University of Idaho, Moscow (E) Collections dated, not numbered. No serial records kept but probably most collections found in IDF, records of 118 sight records from nine plots provided by Tisdale (F) Low Saddle, Cold Springs Cow Camp, Cold Springs L.O., Bald Mountain, and Seven Devils Guard Station pasture (G1) 29 (G2) 29$^+$

(A) Tucker, Helen M. (B) 1932 (C) CIC, ID (D) College of Idaho, Caldwell (E) No records at CIC, search continuing, collections dated, not numbered (F) Rapid River (G1) 2 (G2) 2$^+$

(A) Wellner, Charles A. (B) 1978 (C) ID, IDF (D) Intermountain Research Station, Moscow, ID (E) Wellner's records copied by author (F) Pollock Mountain, vicinities of Sheep, Gem, Echo, Baldy and Little Baldy Lakes (G1) 26 (G2) 26

(A) Wherry, Edgar T. (B) 1940 (C) PH (D) Philadelphia Academy of Natural Sciences, Philadelphia, PA (E) No records at PH, search continuing at University of Pennsylvania (F) Black Lake (G1) (G2) 1$^+$

Range Sciences Research Herbarium, IDF; and the Marion Ownbey Herbarium of Washington State University, WS). These herbarium searches provided much more information confirming the presence of the 535 taxa and extending their known distributions in the Seven Devils. More importantly, it uncovered the names of many others who had collected in the Seven Devils.

3. Notable among these collectors were four botanists whose collections, as found in the herbaria, could be augmented with additional collections reported in their field collection notes. These botanists were John H. Christ of the Soil Conservation Service, U.S. Department of Agriculture (collection ledgers at ID, 435 collections); William H. Baker, former Director, ID (accession books at ID, 219 collections); Harold St. John, Professor of Botany at Washington State [then] College and author of the "Flora of Southeastern Washington and Adjacent Idaho" (1937) (photocopies of Seven Devils field collection notes obtained by correspondence with St. John, 176 collections); and Jacqueline Packard, Washington State College botany graduate student (fragmentary field collection notes obtained by correspondence with Mrs. Jacqueline Packard Moore, 123 collections). These 950 collections included 130 additional taxa, which when checked through the three local herbaria, generated additional names and collections.

4. In addition to the eight collectors or collection parties above, successive herbarium searches, including those at BOIS and OGDF, generated the names of another 37 collectors or parties (table 1). All but two (E. C. Johnson and L. Howell, each having made only one known collection) were located. Thus 35 additional field collection records might be accessible, either through personal correspondence, or if deceased (11 collectors), through an agency. Aided by Steiber's (1982)[1] register of collector's field notes, inquiries were mailed to 34 collectors, their agencies, or herbaria. This effort produced the following results: photocopies of pertinent field notes for 12 collectors; evidence that field records had not been made or had been lost for 10 collectors; a reconstruction of the collection record for four collectors (Baird, Brewer, McDowell, and Simon) by complete searches of the Council R.D. and BKR herbaria; no answers from four presumably living collectors; and inquiries still underway with five collectors.

These inquiries and resultant copies of field records generated the few remaining (17) taxa of the checklist. The 45 individuals or parties known to have collected in the Seven Devils Mountains are listed in table 1, along with summary information on their collections, affiliated herbaria, and places of work.

The 722 taxa checklisted include 72 (10.0 percent) represented only by sight records, which are visual records made by several different plant collectors. Sight records indicate that a given plant was believed to occur, on a given date, on a given sample plot, a section of a road or trail, or in the plant community near a collected plant. Such records are included to cover plant taxa not represented by mounted herbarium collections, to augment the record for rare or scarce taxa, and to contribute to the general statement about the frequency and distribution of each taxon. The preponderance of the sight records came from the sample plot work of Edwin W. Tisdale, emeritus professor of range management at the University of Idaho College of Forestry, Wildlife and Range Sciences; from Charles G. Johnson, Jr., plant ecologist, Wallowa-Whitman National Forest; from Robert Steele, plant ecologist, Intermountain Research Station, Boise, ID; and the trail and roadside surveys of Bingham and Miller as made for their layman's flora of the Seven Devils. The 5,463 sight records are summarized below:

Worker(s)	**Years**	**Number**	**Types and localities of plots or units sampled**
Tisdale	1979	118	Nine sample plots, 15 × 30 m, 5,200-7,800 ft elev., Low Saddle south to Seven Devils Guard Station.
Johnson	1982-1983	1,550	Ninety-one 10.93-m radius circular reconnaisance plots preliminary to habitat typing, 5,100-8,070 ft, Wild Horse Ridge south to the head of Deep Creek.
Steele	1972, 1974, 1981	203	Seven plots, same size and purpose as Johnson, 5,000-6,960 ft, Papoose Creek south to Huntley Gulch (see Steele and others 1981).
Bingham and Miller	1981-1982	3,592	Thirty-eight 1- to 5-mi long trail or road segments, 2,200-9,400 ft, Camp Howard south to Landore.

---

[1] In the checklist dates or names and dates, in parentheses, when not tied to collectors, refer to literature cited.

Accuracy of the identity of collections and sight records undoubtedly varies with the training and experience of the collector or observer, and the expertise the collector enlisted in confirming identifications. In terms of reliability of identification, the collections would rank as follows:

1. Collections identified or verified by specialists in the particular families, sections, or genera.
2. The more recently identified collections (say post-1975) that have been accepted by a recognized herbarium, for the identity of almost all of these are now verified by well-trained taxonomists before being deposited in the herbarium. For example, the 1977-83 collections of Wellner, Henderson, Tisdale, and Bingham and Miller were all verified by such taxonomists.
3. The pre-1975 collections found in recognized herbaria.
4. Collections identified by the collector only in his field notes and not seen or found recorded elsewhere by the author.
5. Mostly unsupported sight records.

Undoubtedly some of the unseen collections are incorrectly identified by the collector in his or her field notes, and they will have been reidentified by taxonomists at the various herbaria. This checklist includes only a few such reidentifications where known to the author through correspondence or through his examination of reidentified collections in the various herbaria searched. The checklist also includes at least 20 taxa that are of questionable identity because they fall outside the known distribution of the taxa. These "off-range" taxa, as well as about 10 other taxa of uncertain identity, are indicated by a question mark preceding the Latin name.

Field notes also vary widely in quality. Christ, for instance, provided only skimpy habitat and locality data for his collections. But he was meticulous in updating his field notes following confirmation of the identity of many of his plants, recording them by collection numbers in a separate set of beautifully handwritten ledgers. Field notes of other collectors, however, commonly included plants known to have been misidentified, numbered plants identified only as to genus, and even unidentified plants.

This checklist includes more than 100 collections by seven different collectors who merely dated, and did not number, their collections. In many cases it has been possible to definitely recognize these dated collections by substituting a given herbarium's number for the missing collector's number, as follows: Aldrich 7/4/07, ID 7824, and so forth. These unnumbered collections undoubtedly occur under different numbers in other herbaria.

Henderson, Kruckeberg, and Wellner (table 1) each entered a few sight records in the course of recording data on other plant collections. In this checklist, about half of the taxa represented by sight records alone are the often-ignored and seldom-collected, common and introduced weeds, or low-elevation taxa seen by Bingham and Miller along the Rapid River.

Checklist Format

Plant taxa are checklisted alphabetically, first by family names, then by genus, species, subspecies, and variety, all in Latin. (Phylogenetic arrangement of families is not attempted.) Latin names are followed by the authorities (usually abbreviated) and the taxon's common name, amplified as necessary to distinguish subspecies and varieties. Latin names and most of the common names follow "Flora of the Pacific Northwest, an Illustrated Manual" (Hitchcock and Cronquist 1973), except as follows: For the *Artemisia tridentata* varieties see Winward and Tisdale (1977), for the *Hieracium* species and varieties of Section Thyrsoidea see Deardorff (1977), for the *Poa sandbergii* (or *P. secunda*) complex see Arnow (1981) or Kellogg (1983), for the North American *Salix* species of Section Cordatae see Dorn (1975), and for the *Thlaspi fendleri* (or *T. montanum*) complex see Holmgren (1971).

Next follows a general statement covering the relative frequency of the taxon and outlining its locality and elevational distribution, based on all known collections and sight records. Relative frequency of a taxon is given in terms of the number of known occurrences (collections and/or sight records), as follows:

Rare—currently listed by Steele and others (1981) among endangered, threatened, or plant of concern in Idaho, not exotics.

Scarce—only one or two known occurrences, often because the taxon normally occurs at elevations either lower or higher than found in the Seven Devils Mountains.

Occasional—three to four known occurrences, sometimes because it usually occurs at lower or higher elevations.

Uncommon—five to nine known occurrences.

Frequent—10 to 19 known occurrences.

Common—20 to 39 known occurrences.

Abundant—40 or more known occurrences.

Elevations do not apply to the Rapid River unless the plant was collected or seen only there. General localities are given as northern Seven Devils (north of Crater Lake), central Seven Devils (Crater Lake south to Emerald Lake), southern Seven Devils (south of Emerald Lake), and Rapid River (lower and west fork along trail 113 up to Rankin Mill). Occasionally, in successively numbered collections, the locality and elevational information has been inferred from the collector's field notes for previously or subsequently numbered collections.

Next follows a list, alphabetically by collector's names and then numerically by collector's numbers, of all known collections of the taxon. As mentioned above, sight records may be included in certain cases, and their number is included in most cases. Each collection number is followed by the abbreviations (table 2) for the herbaria known or assumed to hold the collection, and is accompanied by a brief description of habitat, locality, elevation, and date of the collection, as available from notes and herbarium label.

A single asterisk preceding the collector's name signifies a collection known only from the collector's field notes, and identified there only by the collector. In most cases it is known that the collectors deposited specimens of given periods in certain herbaria, while in other cases a collector donated or sold part or all of his personal herbarium to a particular institutional herbarium. For instance, the Washington State University botanists St. John, Meyer, Packard, Comstock, Aase, Munro, Jones, and others are known to have deposited their Seven Devils plant collections in the Ownbey Herbarium at that institution, while Christ, late in his life, is known to have sold his principal and personal collection to the

Table 2—List of abbreviations for herbaria where Seven Devils Mountains plants have been deposited

Abbreviations	Herbarium address
ASC	Deaver Herb., No. Ariz. Univ., Flagstaff
BKR	District Herb., Baker, OR Dist., Bur. Land Manage.
BOIS	Intermountain Res. Stn., USFS, Boise, ID
CAS	Calif. Acad. Sci., San Francisco
CIC	Helen M. Tucker Herb., College of Idaho, Caldwell
Council R.D.	Council Ranger District, Payette NF, Council, ID
F	Field Museum of Natural History, Chicago, IL
GH	Gray Herbarium, Harvard Univ., Cambridge, MA
ID	Dept. Biol. Sciences, Univ. Idaho, Moscow
IDF	Coll. For., Wildlife and Range Sci., Univ. Idaho, Moscow
IDS	Ray Davis Herb., Idaho State University, Pocatello
MICH	University of Michigan, Ann Arbor
MO	Missouri Botanical Garden, St. Louis
MONTU	University of Montana, Missoula
NA	U.S. National Arboretum, Washington, DC
NY	New York Botanical Garden, Bronx Park, New York City
OGDF	Forest Service, Intermountain Region, Ogden, UT
ORE	University of Oregon, Eugene
OSC	Oregon State College, Corvallis
PH	Phila. Acad. Natural Sci., Philadelphia, PA
RM (incl. USFS)	Rocky Mt. Herb., University of Wyoming, Laramie
RSA (old POM)	Rancho Santa Ana Botanic Garden, Claremont, CA
US	U.S. National Herb., Smithsonian Inst., Washington, DC
USFS	See RM, above
UTC	Intermountain Herb., Utah State University, Logan
WS	Marion Ownbey Herb., Wash. State University, Pullman
WTU	University of Washington, Seattle
WWB	Western Washington University, Bellingham

New York Botanical Garden. In cases where the author has not seen the collection, but has assumed it to be deposited in a given herbarium, or where the collection has not been seen because it is out on loan or lost from a local herbarium, the herbarium acronym is preceded by a question mark. These collections then appear in the checklist as follows:
Christ 12733, ?NY, ...

Where locality may have been refined, updated, and amplified by the author, such information is enclosed in parentheses. Local or obsolete place names appearing more than twice in this checklist are defined below. Interpretation of most of these names was provided for the central Seven Devils by Ace (Ralph A.) Barton of Riggins, ID, or by Earl E. or Esther C. Hibbs of Pullman, WA, and for the southern Seven Devils by Walter W. Pierson, one of the range management veterans still with the Payette National Forest, McCall, ID.

"**Brundage Trail**"—a name used by Packard (1937 and 1938 collections) that refers to the original (and several-times-relocated) Forest Service trail 112, as located and partly constructed by Ranger Lew Bundige about 1911. The misspelling is Packard's.

"**Camp Howard, 5,000 ft**" of Aldrich (Colls. of 1907), probably refers to the general area of the Camp Howard Cow Camp in the headwaters of Getta Creek on Camp Howard Ridge about 5 mi west-southwest of the town of White Bird, ID. The present Cow Camp lies at 5,700 ft elevation.

"**Dry Diggins**" or "**Dry Diggins Area**" referred to by St. John and Mullen (Colls. of 1927), Packard (Colls. of 1937 and 1938), Nelson and Nelson (Colls. of 1938), Esther Hibbs (Colls. of 1937), and Kruckeberg (Colls. of 1952) is a name conferred by the early stockmen. It refers to a mostly lava-capped plateau extending southwest from the south end of Dry Diggins Ridge and Lily Pad Lake toward Hibbs Cow Camp along the divide between Bernard Creek to the northwest and the west fork of Sheep Creek or Little Granite Creek to the southeast. It does not refer to the area around Jack Hasting's Dry Diggins Ridge mining claim to the north along trail 140, nor to the area in the immediate vicinity of Dry Diggins Lookout.

"**Dry Diggins Camp**" or "**Dry Diggins Ranger Station**" as referred to by Nelson and Nelson (Colls. of 1938), apparently was a name coined on the spot and it cannot be located. This place (or places) may have been a temporary lookout, fire camp, or fencing camp. It was not Dry Diggins Lookout because the Nelsons collected there and specifically identified the lookout.

"**Granite Creek, White Cabin**" of Ranger Brewer (Colls. of 1928), may refer to a white-painted cabin or one occupied by a person named White. The site is one of the abandoned cabins at or near Deb's Corral at the junction of trails 192 and 189, just east of Granite Creek and Stevens Saddle, but in the head of the west fork of the Rapid River; or it is some unknown cabin on the Granite Fork of the Lake Fork of the main Rapid River, possibly lying along either Black Lake road 112 or the Lake Fork trail 188. Brewer's data as to General Land Office sections, townships, and ranges often were in error. Here he gave the locality either as sec. 11, T. 22 N., R. 2 W., or as sec. 10, T. 22 N., R. 3 W.

"**Heavens Gate**" of Ownbey and Meyer (Colls. of 1940), Aase (Colls. of 1940), Davis (Colls. of 1940), and to some extent Baker (Colls. of 1954) and Christ (Colls. of 1941), may include part or even all of the ridge along the Snake-Salmon Rivers divide between Windy Saddle and Heavens Gate Lookout.

"**Horse Heaven Saddle**" of Bingham and Miller (Colls. of 1980 and 1981) is the author's name for the somehow unnamed but major saddle at the heads of Two Creek and the north fork of Mill Creek, where the Old Boise Trail joins trails 114 and 124 about one-fourth mi north of Horse Heaven Lookout cabin.

"**Iron Springs Ranger Station or Camp**" of Brewer (Colls. of 1928) was an early Forest Service camp located at the spring about 0.2 mi north of Holbrook Saddle near the junction of trails 190 and 191. According to Walter Pierson it was not at the site of the old town of Iron Springs on upper Paradise Creek.

"**Jackley Guard Station or Guard Camp**" of Brewer (Colls. of 1930) was a tent camp located near Jackley Mountain.

"**Krammer, or Krammer Cabins**" of Brewer (Colls. of 1929) apparently was near the junction of roads 105 and 112, about 1¼ mi north of Bear Guard Station. This was the Kramer (stage) station discussed by Pam Gardner (March 1986) in the Forest Service Region Four Intermountain Reporter.

"Patrolman Creek" of Brewer (Colls. of 1928) was a small and now apparently unnamed creek lying to the north of Jackley Mountain and probably draining into Oxbow Creek and the west fork of the Rapid River.

"Rapid River Trail" of the Nelsons (Colls. of 1938) could be their name for the main Rapid River trail 113, or for any of the trails (55, 61, and 62) which parallel the river or leave the west fork to climb up to the Old Boise Trail, above.

"Seven Devils Camp" of Christ (Colls. of 1941) and Baker (Colls. of 1954) was the old unimproved campsite at the former terminus of road 517 at Windy Saddle. The present-day camp (as referred to by Bingham and Miller 1979, 1981; or LaZelle 1963) was not constructed until about 1959-62.

"Seven Devils Forest Station" of Kruckeberg (Colls. of 1952) or **"Administrative Site"** of LaZelle (Colls. of 1963) was the present-day Guard Station about one-fourth mi southeast of Windy Saddle.

"Seven Devils Ridge" of Christ (Colls. of 1941) apparently is a name coined by Christ and defies interpretation. It could be either the ridge between Windy Saddle and Heavens Gate Lookout or the ridge along the divide between Bridge and the west fork of Sheep Creeks. From Christ's other collections of the same day near Seven Devils Lake, it would appear to be the latter.

"Sheep Creek" of Davis (Colls. of 1940), **"Headwaters of Sheep Creek"** of Ownbey and Meyer (Colls. of 1940), and **"Sheep Creek Trail"** of Christ (Colls. of 1941) all refer to the east and west forks of Sheep Creek where traversed by trail 112 between Windy Saddle and the south end of Dry Diggins Ridge.

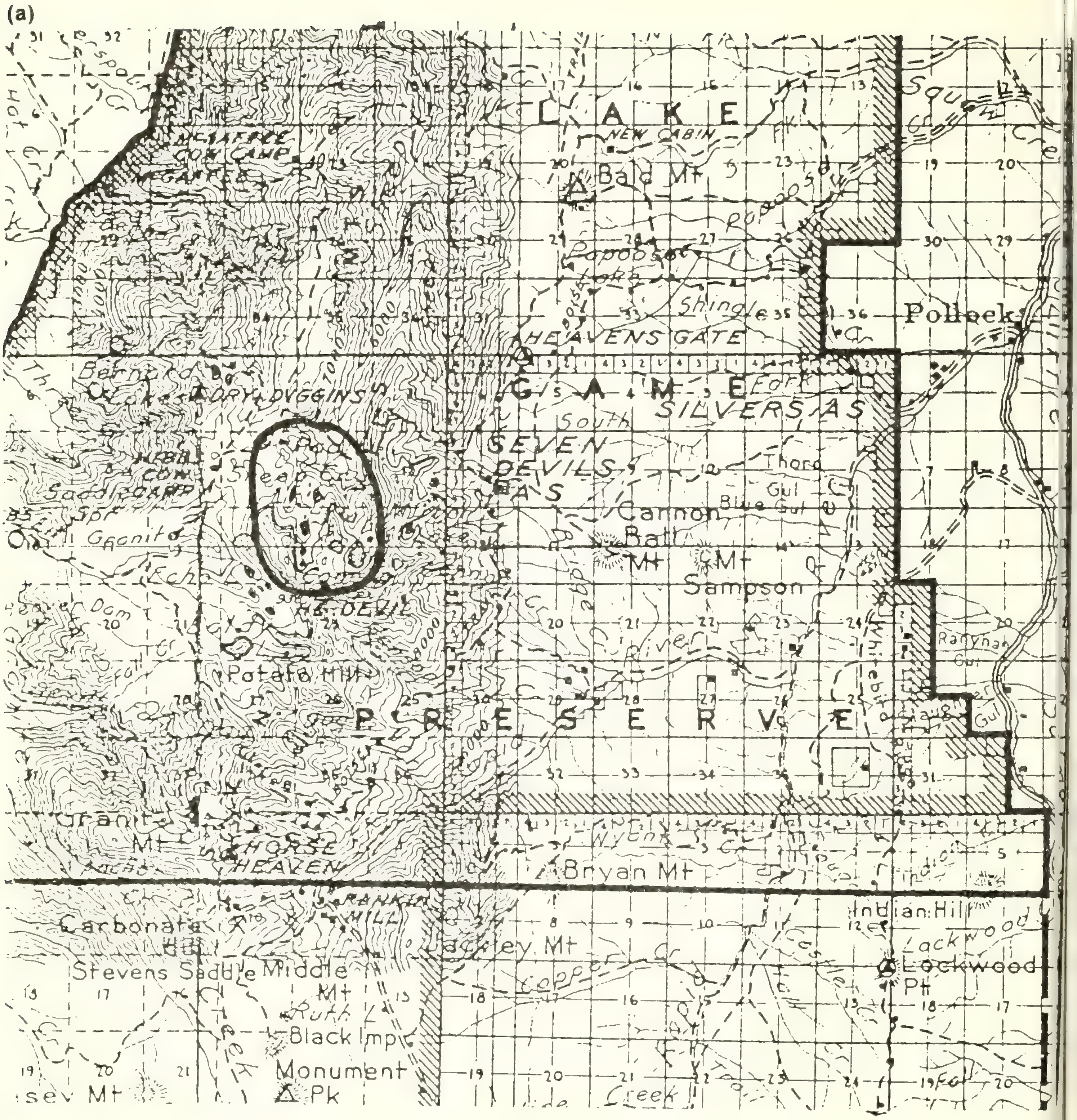
"Sheep Creek Lakes No. 1 to 4" of Packard (Colls. of 1937), Christ (Colls. of 1941), and Kruckeberg (Colls. of 1952) are names reflecting the fact that—aside from Lily Pad Lake—the lakes in the head of the west fork of Sheep Creek which, although mapped, remained unnamed until the early 1940's (see portion of Packard's 1931 Nez Perce NF map, fig. 1a). Ace Barton says (Barton 1984): "There was no trail into Sheep Lake at that Time, just a way through. My folks and the Hibbs got to calling the lakes 1-4 and the name stayed until Lithicum did his survey in the Forties. As far as I know he named them with the present day names. . . . The numbers corresponded with lakes as you came on them from the Dry Diggins side." Thus as one proceeded south from Lily Pad Lake, alongside or across "The Swamps" (see below) on some forerunner of trail 123, Basin Lake became Lake No. 1, Shelf Lake No. 2, and Gem Lake No. 3. Apparently the other two lakes (Rock Island and Appendix) above Gem Lake in the very head of the west fork of the west fork of Sheep Creek were hidden from view on the old trail 123 (as with the present trail), and thus were not numbered. The trail then crossed the divide between the east fork and the west fork of the west fork of Sheep Creek, and descended to Lake No. 4 (Sheep Lake).

"Sheep Peak or Rock" of Brewer (Colls. of 1928) is the 5,257-ft Sheep Peak (or Mountain) lying about 1¼ mi northwest of the Wildhorse River and about 5 mi south-southeast of the Snake River Oxbow. It is not the present-day Sheep Rock at the northern terminus of road 106, about 7 mi north of Cuprum.

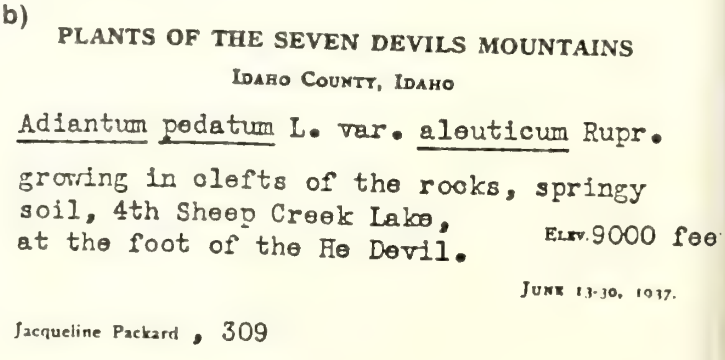
"Squaw Creek" of Meyer (Colls. of 1937), Moore (Colls. of 1936), Munro (Colls. of 1937), Packard (Colls. of 1936), Peters (Colls. of 1936), and St. John and Mullen (Colls. of July 17-19, 1927) is an old name now changed to Bernard Creek to avoid confusion with the Squaw Creek entering the Little Salmon River just south of Riggins.

"The Swamps" of Packard (Colls. of 1937), E. Hibbs (Colls. of 1937), and Christ (Colls. of 1941) is another well-deserved name conferred by the early stockmen to the long and often very wet sedge meadow lying along the west side of present trail 123 between Lily Pad and Basin Lakes.

The checklist includes 13 of Idaho's rare plants, so designated by Idaho's official rare plant group, The Rare and Endangered Plant Technical Committee of the Idaho Natural Areas Council. These rare plants are identified by a double asterisk preceding the Latin name. Among the 13 rare plants, two have been recommended for the Federal-Threatened category. These plants are rare in the United States and likely to become endangered due to declining populations or to the likelihood that their habitat area will decrease under present land use or management practices. Another six plants are recommended for a "Federal Watch List," and another five plants for a "State Watch List." These are plants the Committee feels should be monitored. They are rare, either in the United States or in the State of Idaho, even though not now threatened unless major changes occur in the management of lands where they occur. See Steele and others (1981, rev. 1983) for more


(a)
LAKE
NEW CABIN
Bald Mt
Papoose Lake
Shingle
HEAVENS GATE
Pollock
GAME
SILVERS AS
South Fork
SEVEN DEVILS AS
DRY DUGGINS
Thorn Gul
Blue Gul
Cannon Ball Mt
Mt Sampson
HE DEVIL
Granite
Beaver Dam
Potato Hill
River
PRESERVE
Rapynah Gul
Granite Mt
HORSE HEAVEN
Bryan Mt
RANKIN HILL
Carbonate Hill
Stevens Saddle
Middle Mt
Black Imp
Monument Pk
Copper Cr
Creek
Indian Hill
Lackwood
Lockwood Pt

(b)



PLANTS OF THE SEVEN DEVILS MOUNTAINS

Idaho County, Idaho

Adiantum pedatum L. var. aleuticum Rupr.

growing in clefts of the rocks, springy soil, 4th Sheep Creek Lake, at the foot of the He Devil. Elev. 9000 fee

June 13-30, 1937.

Jacqueline Packard, 309

Figure 1—(a) Jacqueline Packard's 1931 Nez Perce National Forest map showing the then unnamed lakes (circled) south of Lily Pad Lake in the head of Sheep Creek; and (b) her personal herbarium label, this one covering the new and rare maidenhair fern taxon from the Sheep Lake (4th Sheep Creek Lake).

details on the status and distribution of these rare plants. Seventeen other plants, previously considered as potentially rare, currently are known to range in frequency from fairly common to scarce and are not designated otherwise (see Henderson and others 1977).

Last, the checklist includes 52 plants introduced from Eurasia. These are identified as to continent of origin by parenthetical notes following the common name. The introductions make up just over 7 percent of the Seven Devils Mountains flora.

GEOLOGICAL HISTORY AND GEOLOGY OF THE SEVEN DEVILS MOUNTAINS

Some 14 to 17 million years ago in the Miocene Geologic Period two extensive and now rather well-defined basalts were extruded from a volcanic chain located near the junction of Washington and Oregon with Idaho. These were the older Imnaha and the younger Grande Ronde Basalts, and they spread to cover most of the southeastern portion of the ancestral Columbia River Basin, including the ancestral Snake River and its tributary Salmon, Little Salmon, and Weiser River drainages (Hooper 1982). Then, probably about 11 to 13 million years ago (still in the Miocene) the Seven Devils, Wallowas, Owyhees, and other mountain ranges ringing the upper Snake River Basin were uplifted, trapping the Snake River and backing it up to form ancestral Lake Idaho (Livingston 1928). The rising lake, which stretched from Oxbow to Twin Falls, may for a time have drained westward through southern Oregon or farther to the south through Nevada and northern California. Eventually, however, it found a northerly outlet near Oxbow. Then in only the last 2 million years the new Snake River, following a series of north-south fault lines, very rapidly cut down the magnificent, present-day Hells Canyon (Wheeler and Cook 1954). This process was greatly hastened by Pleistocene-Era glaciation of 1 to 2 million years ago.

To the northwest and west of the Seven Devils in the northern Blue Mountains and often-plateaued Wallowa Mountains, and to the south in the smaller and lower, plateaued Cuddy Mountains, the uplifted basalt cap often remains in place over fairly large areas between 6,000 and 8,000 ft elevation (Livingston 1928). This is not the case, however, in the much narrower and consequently much more severely eroded Seven Devils Mountains. Exemplifying the severity of this erosional stress, a 13-mi east-west transect through 9,393-ft He Devil Mountain rises 7,000 ft in 7 mi from the Rapid River on the east, and then falls 8,000 ft in 6 mi into Hells Canyon on the west. Under these conditions it is easy to visualize the erosional undermining and removal of most of the basalt cap from atop the central Seven Devils. In areas of lesser uplifting and erosional stress, as, for instance, in the northern Seven Devils at 5,000 to 6,000 ft along the Snake-Salmon Rivers divide between Buckhorn Spring and Camp Howard Triangulation Station, the basalt mantle has yet to be eroded away. Continuous stretches of Imnaha Basalt, occasionally overlain by the younger Grande Ronde Basalt, remain in place along that divide today. Similarly, in the southern Seven Devils, some fairly large or continuous areas of these same basalts are found in two general areas. One of these areas is along the Snake-Weiser Rivers divide on either side of the Black Lake road near Placer Basin. Here, at 5,500 to 6,500 ft, the younger and higher Grande Ronde Basalt, if ever there, is gone, but the older and lower Imnaha Basalt remains atop several half-square-mile to square-mile areas. And in the other area farther to the south and west, on the 4,500- to 5,200-ft plateaued ridges constituting the Indian Creek-Snake River and the Wildhorse-Snake Rivers divides from west of Cuprum on the north to Sheep Peak (not Rock) on the south, even the Grande Ronde Basalt remains uneroded atop the older Imnaha Basalt.

Only one, perhaps third-square-mile, patch of Imnaha Basalt (severely weathered) remains in the central Seven Devils—on the 7,300- to 7,600-ft plateau which forms the Bernard Creek-Little Granite Creek divide and lying between the junction of trails 112 and 140 (south end of Dry Diggins Ridge one-half mile north of Lily Pad Lake on the northeast) and trails 112 and 56 about one-fourth mile north-northeast of Hibbs Cow Camp (Gaston and Bennett 1979). This remnant of basalt is the substrate for one of the few disjunct plant communities of the Seven Devils. This is the only central Seven Devils locality where one finds dagger pod (*Phoenicaulis cheiranthoides* Nutt.), Bolander's yampa (*Perideridia bolanderi* (Gray) Nels. and Macbr.), barestem desert parsley (*Lomatium nudicaule* (Pursh) Coult. and Rose), and the hairy-bracted variety of Eatons daisy (*Erigeron eatonii* Gray var. *villosus* Cronq.). Except for the subalpine components (subalpine fir, mountain bog gentian, etc.), the plant community is almost as if lifted piecemeal from the basalts of Midvale Summit along U.S. Highway 95 about 55 mi to the south-southeast.

Thus, remaining atop most of the central Seven Devils are the uplifted and metamorphosed, "undifferentiated" (meaning little known) rocks called the Seven Devils Group (Gaston and Bennett 1979). Even casual observation shows that there is considerable variation in these rocks, but they remain unclassified.

Glacial moraines lie both east and west of the central Seven Devils, mostly below 6,500 ft elevation. On the east an extensive moraine perhaps 5 mi^2 or more in area extends for more than 5 mi between the Old Boise Trail 101 and the West Fork of the Rapid River, from about Horse Heaven Creek on the southwest to Bridge Creek on the northeast. On the west, another much smaller, perhaps half-square-mile moraine lies in Little Granite Creek below Baldy Lake and trail 124, mostly between the main forks of the creek. Other breaks in the seeming monotony of the Seven Devils Group rocks are the granitelike, usually light-colored, igneous intrusives (granodiorites, quartz diorites and monzonites, diorites, and gabbros) found covering several square miles in upper Devils Farm Creek and extending northwestward across Little Granite Creek to the Three Creek Divide. Similar light-colored intrusives are highly visible in another 5-mi^2 area—the White Monument area of the Southern Seven Devils—lying between the Sheep Rock road 106 on the west and reaching into the head of Deep Creek below High Dive on the Black Lake road 112 on the east (from 5,400 ft to 8,300 ft), as well as in a 2-mi^2 area surrounding Echols Mountain (6,800 ft to 8,300 ft). There are no obvious vegetational changes associated with either the moraines or the granitelike intrusives.

There is no true alpine timberline even on the highest of the Seven Devils Mountains (He Devil, to 9,400 ft; She Devil, 9,300 ft). Weatherbeaten and runty whitebark pines (*Pinus albicaulis* Engelm.) and subalpine firs (*Abies lasiocarpa* [Hook.] Nutt.) grow in the rock crevices atop these highest peaks. And because of the steep upper slope gradients characterizing the severe erosional stress of the central Seven Devils, there appear to be none of the perched and poorly drained small plateaus that might support the tundralike vegetation often found elsewhere at these elevations.

BOTANICAL HISTORY OF THE SEVEN DEVILS MOUNTAINS

Over the past 88 years, more than 40 plant collectors or two-person collection parties have collected in the Seven Devils Mountains and have deposited plants in many herbaria across the United States. The pioneer collectors seem to have been the two self-taught, but skilled and recognized botanists, William C. Cusick and Marcus E. Jones. Both of them collected in the southern Seven Devils in 1899.

Cusick, who made most of his living from a farm near Union, OR, collected plants over much of eastern Oregon, particularly in the Wallowa Mountains. In July and again in September of 1899, however, he crossed the Snake River into Idaho (almost certainly at Ballard's Ferry 3 mi below Homestead) and collected plants along the then 10-year-old Kleinschmidt Grade, from the Snake River via Cuprum to Old Helena and the nearby Peacock mines. That grade, viewed today as frighteningly steep, had been completed in 1891 by mining entrepreneur Albert Kleinschmidt. But as late as 1920 it was described by visiting geologists as "well located. . . by far the best graded road the writers have seen in the state" (Carrey and others 1979). Among the more interesting plants Cusick collected on these two trips were the type collections of the Idaho variety of the white-stemmed frasera (*Frasera albicaulis* Dougl. var. *idahoensis* [St. John] Hitchc.), of which an isotype is held at WS, as well as the scarce tall phacelia (*Phacelia procera* Gray). The frasera now is recommended for a "Federal Watch List" by the Idaho Rare and Endangered Plants Technical Committee (Steele and others 1981, rev. 1983).

Marcus E. Jones was a mining engineer-botanist. From July through December of 1899 he collected plants, while secretly he prospected for coal deposits for the then new Pacific and Idaho Northern Railroad (now the Union Pacific line from Weiser to Tamarack) (Lenz 1983a). In that year, the new railroad was starting a line from Weiser, supposedly to the Helena (Peacock) mines (Carrey and others 1979). Work on the Helena end of that grade had begun in 1900 (Carrey and others 1979), and before the railroad diverted its line to New Meadows, and as pointed out by the Payette National Forest sign along road 106 south of Kinney Point, over a million dollars was wasted on the Helena-end grade. To the author's knowledge, Jones collected only one plant in the Seven Devils: No. 26583, collected at 6,000 ft elevation August 5, 1899, and much later designated by C. P. Smith as the type of a supposedly new lupine, named after the Seven Devils as *Lupinus diaboli-septem* (Smith 1951). Jones' journal, transcribed by Rancho Santa Ana Botanic Garden Director Lenz, indicates that he was constantly collecting plants in the summer and fall of 1899; also that he often was in the Cuprum area. But, because Jones kept no field collection notes until later in his life (Lenz 1983a) and because his journal is blank for the period July 19 to September 19, 1899, we do not know where in the Seven Devils he might have been on August 5, 1899, let alone what else he might have collected there. Jones' journal does reveal that while visiting mining claims near Baker, OR, he made a circuitous and probably difficult, 3-day side trip (March 6-8, 1900) to visit William Cusick. Jones decribes Cusick as "a farmer, poor, a Christian man, widower, 58 years old, and a very fine man." He and Cusick spent more than a day going over the latter's plants (Jones' journal as transcribed and provided by Lenz).

The next known collector of Seven Devils plants, in 1907, was John M. Aldrich, a Professor of Biology (1903-1913) and founder of the Department of Entomology at the University of Idaho. He was a close friend of the first University of Idaho botanist and plant collector Louis F. Henderson. Henderson (undated) reported having eight 45-minute classes every school day shortly after he reported to the new university in 1893, and that his colleague Aldrich carried a similar load. Henderson attributes to Aldrich, in answer to an inquiry as to which chair he occupied at the university, the remark, "We didn't any of us occupy 'chairs'—we all occupied settees!" Henderson (undated) also describes the burning of the University's main building in March 1906 as "when a disastrous fire swept off our large University building, and with it went all my equipment and my herbarium which had taken 25 years to make and was one of the joys of my life." Of course, Aldrich's 1907 collections escaped the fire and now are among the oldest at Idaho with accession numbers as low as 2264. Only 14 of Aldrich's Seven Devils collections have been found so far, all from the Camp Howard area in the extreme northern Seven Devils. Even so, they attest to Aldrich's diligence, since 12 of the 14 were made on the 4th of July.

There then occurred a 20-year hiatus in Seven Devils Mountains plant collecting. Serious plant collection began in the area in 1927. It was then that Harold St. John, a young Harvard Ph.D. and professor, and Lowell A. Mullen, student in the Washington State (then) College Department of Botany, mounted an 11-day plant collecting foray into the Seven Devils. They hired a packer-guide and rented saddle and pack stock, probably at the Reeves Ranch 2 mi southwest of Riggins at the mouth of Papoose Creek. Starting from there (2,400 ft elevation) in the early morning of July 17, 1927, they first ascended Squaw Creek about 3 mi on trail 110, then branched off to the right on the Indian Springs trail 46 and ascended past Lime Saddle about 3 more miles to the Old Boise Trail 101 on the Snake-Salmon Rivers divide about one-third mile south of Fire Camp Saddle. Then they proceeded southward 2 mi up the divide until they rejoined trail 110 just south of the treacherous stretch of trail 101 called The Narrows (7,600 ft). Here they turned westward again and proceeded down past the Old Timer Mine and the Forks of Sheep Creek (4,000 ft) and up the Sawyer-Bear Trap Creeks ridge to the Sheep-Bernard Creeks divide (7 mi, to 6,000 ft). Finally they descended, still westward, down the quarter-mile of trail 110 remaining for them to reach their first night's goal at the McGaffee Cow Camp (5,700 ft). Earl Hibbs, the youngest son (now in his mid-seventies) of the Martin Hibbs family (Granite Creek and Hibbs Cow Camp cattlemen) assures me that the old-timers often made **round** trips like that in those days (Hibbs 1984), but it would be a safe bet that the greenhorn botanists were tired and saddle-sore that night. They had collected only 15 plants during the long but busy day, but they had ridden about 15 rough, horizontal miles and 1⅔ vertical miles.

On July 18 and 19, the two botanists, belying any exhaustion, logged another 1⅔ miles vertically, westward down trail 110 to the Snake River at the mouth of Bernard Creek (1,400 ft) and back up to the Cow Camp, meanwhile collecting another 40 plants. Then on July 20 they headed south toward the high country, ascending the Dry Diggins Ridge trail 140 into the central Seven Devils. Considering that they had only the old-fashioned vasculums (loose-lidded, cylindrical, sheetmetal cans) for holding plants while preventing their withering prior to pressing, it is remarkable that they were able to collect and press more than 60 different collections that day. Some of the plants must have been pressed en route. On July 20 and 21, working on what they called the "Dry Diggins Area" (see discussion under "Checklist Format") at elevations they gave as 7,500 ft to 8,000 ft, they collected and pressed another 35 plants.

The high point of St. John's and Mullen's trip, literally and figuratively, came on July 24, when they climbed He Devil Mountain. Starting point, route, and mode of travel are uncertain, but either going or returning to the vicinity of Lily Pad Lake they apparently descended into the head of the Echo Lake Fork of Little Granite Creek. About 50 collections were made while approaching or on He Devil Mountain. The taxa they collected as well as the elevations (for instance, 8542, *Eriogonum ovalifolium* Nutt. var. *depressum* Blank., summit of He Devil, 9,200 ft) certainly attest to their reaching the summit—and long before the Mazama Club established a climber's register there. Among the more interesting collections made on or near He Devil Mountain was the initial collection of what may prove to be a new variety of maidenhair fern (*Adiantum pedatum* L.; see body of checklist for more details on this taxon). Other uncommon plants collected that day were the alpine lily (*Lloydia serotina* [L.] Sweet), and dwarf hulsea (*Hulsea nana* Gray). On July 25 and 26, they broke camp near Lily Pad Lake and returned to the Reeves Ranch via McGaffee Cow Camp and Sheep Creek, making more than 35 collections en route. They must have made a side trip well down Sheep Creek, for a timothy (*Phleum pratense* L.) collection of July 26 is labeled "garden clearing by cabin in Sheep Creek, 2,000 ft." Altogether, they made over 240 collections on the 11-day trip, 176 of them from above 5,000-ft elevation. Almost all of these collections remain in WS. The above four paragraphs are based on photocopies of St. John's field collection notes and his letter of October 18, 1982 (St. John 1982).

Although St. John remained at Washington State College only through 1929, his "Flora of Southeastern Washington and of Adjacent Idaho" (St. John 1937) was not published until 8 years later. This flora includes treatment of St. John's Seven Devils collections. St. John must have imparted a real appreciation of Hells Canyon and the Seven Devils Mountains to his students and instructors at Washington State College. He states (St. John 1982) that he made "eight or nine trips by boat from Lewiston up into Hells Canyon and made numerous collections." These annual field trips led by St. John, Hannah Aase, Lincoln Constance, Reed Rollins, Frederick Meyer, and probably other professors and instructors of botany were staged by the Natural History Club and continued for more than 15 years, up to World War II. This checklist includes collections made off the river, but from above 5,000 ft, by seven different Washington State College graduate or undergraduate students from 1936 to 1939 (see Comstock, Meyer, Moore, Munro, Packard, Peters, and Sharsmith, table 1). Lincoln Constance and Reed C. Rollins, then professors at Washington State College, also collected extensively in Hells Canyon in 1936 and named the uncommon or rare Snake River Canyon endemics *Arabis crucisetosa* and *Mirabilis macfarlanei*. Constance, in the spring of 1937, attempting to reach the higher elevations along road 517, drove up Squaw Creek and lower Papoose Creek on May 29. He made at least five collections (1,848-52) between 2,500 ft and 4,000 ft elevation, but was stopped above that by snow.

Next among the early Seven Devils plant collectors was Vernon M. Brewer, who was the Ranger at the Weiser (now Payette) National Forest's Bear Ranger Station (now Guard Station) 25 mi northwest of Council, ID. The district had a large acreage of summer rangeland, and, undoubtedly, range management problems made heavy demands on Ranger Brewer's time. In any event, he became a plant collector, sending a few of his plants to the College of Forestry at Moscow for identification or verification. His known collections made between 1928 and 1931 have numbers between 5 and 147, and 95 of them have been found (73 by supervisory forestry technician James N. Camp in the Council R.D. herbarium, and 22 by the author in IDF and Council R.D. herbaria). Later, while ranger at the old Hornet Station 12 mi northwest of Council, Brewer became so embroiled in controversy with grazing permitees that he was transferred to Wyoming (Pierson 1983).

Jacqueline Packard, another member of the Washington State College Botany Department, was also an early and important plant collector in the Seven Devils Mountains. Packard became friends with Esther and Earl Hibbs as an undergraduate at WSC and on collecting trips into Hells Canyon. In 1938 she embarked on a Master of Science program, with the thesis to be a flora of the Seven Devils Mountains (see copy of herbarium label, fig. 1b). This thesis, however, was destined never to be finished, for at the University and on Hells Canyon field trips she met forestry student William R. Moore (table 1). With the Natural History Club, they collected plants together near McGaffee Cow Camp in May 1936, and (the whole Club staying at the Hibbs Ranch) in lower Granite Creek and along the Snake River as far up as Brush Creek in April 1938. In 1940 Packard married Moore, a graduate forester, and moved with him to a job with the Border Patrol in Texas. She was thus forced to abandon her Master of Science degree. Beginning as an undergraduate in 1936, and continuing as a graduate student in 1938 and 1939, Packard had made over 400 collections in the Snake River Canyon and in the Seven Devils. More than 120 of these were from above 5,000 ft elevation in the Seven Devils and were made mostly in 1937 and 1938 while staying with the Hibbs. Almost all of these collections remain in WS.

Packard sent the author a typed account of her June 13-30, 1937, collection trip, when she lived with the Hibbs at the Granite Creek ranch and their Cow Camp in the head of the north fork of Little Granite Creek. This "journal" contains many interesting anecdotes, only one of which will be repeated here. Packard had written friend Esther Hibbs, then at the Granite Creek ranch, that she (Packard) would arrive on a certain day at Johnson Bar on the Snake River via the riverboat "Chief Joseph." But on arrival no one met her with the expected saddle horse. Somehow she tied her heavy and bulky plant press on her packsack and began the 10-mi hike upriver to Granite Creek. She saw no one until she accidently met Earl Hibbs on horseback near the mouth of Granite Creek, only a half-mile short of her destination. Earl now suggests that she may have arrived on the same boat as her letter.

As indicated by the herbarium label illustrated in figure 1, Packard was the second person to collect the rare maidenhair fern of the Seven Devils. Her collection likely is from the identical locality as St. John and Mullen's 1927 collection, and Wellner's or Bingham and Miller's later collections, west of Sheep Lake.

The Moores, now retired and living in Novato, CA, mailed the author a large packet of materials, including Packard's thesis outline and map, photos, some of their original field collection notebooks, rough herbarium labels covering collections other than 1937-38, plus many notes on the collections of others (Comstock, Constance, Hibbs, Meyer, Munro, Peters, Sharsmith, and St. John; table 1). With the Moores' permission, eventually these will be deposited with the Marion Ownbey Herbarium or the Washington State University Library archives.

Eminent among plant collectors of the 1930's to 1950's, and in order of number of plants collected in the Seven Devils, were (1) John H. Christ, USDA Soil Conservation Service, Portland, OR; (2) William H. Baker, Department of Biological Sciences and former Director of the University of Idaho Herbarium, Moscow, ID; and (3) Ray J. Davis, founder and first director of the Idaho State University (now Ray J. Davis) Herbarium, Pocatello, ID. Christ, who spent a lifetime collecting mostly Idaho plants, often as a backpacker in the most remote areas, indeed was indefatigable—his collections totaled over 19,000 (collection ledgers, beautifully handwritten and updated after verification of plant identities, are at ID). His industry as a collector is exemplified by the fact that in a single day, covering several miles of extremely rough and broken terrain near Black Lake in the southern Seven Devils, he gathered and pressed 128 separate collections. Late in his life, Christ sold his personal and main herbarium to the New York Botanical Garden (NY), although about a quarter of his collections can be found in ID and WS.

Baker was the only early collector known to have covered the White Bird Ridge portion of the Seven Devils, between the Little Salmon and Rapid Rivers. His rough accession notebooks, covering over 19,170 collections, are at ID, and almost all of his Seven Devils collections remain there. Davis, author of the "Flora of Idaho" (1952), apparently made only one whirlwind collection trip into the Seven Devils, from June 24 to July 3, 1940. On the June 26-28 part of this trip, he probably joined Marion Ownbey, Hannah Aase, and Frederick Meyer of the Washington State College Botany Department (then with students on a spring field trip), and collected with them at Heavens Gate, along trail 112, at Dry Diggins Lookout and at Bernard Lakes. It is very uncertain from Davis' collection numbering, but he could have made as many as 100 to 150 collections in the Seven Devils. Only about 45 of these have been found in ID and WS, however. Most of the remainder can only become known through a herbarium search at IDS because Davis' field collection notebooks were discarded when his Pocatello home was closed by his children in 1982 (Davis 1983). Davis' northern Idaho collections were quite skimpy, and in "Flora of Idaho" he relied heavily on the collections of John H. Christ and C. Epling. Details of the range of Christ, Baker, and Davis collections will be found in table 1.

Five other well-known botanists, each of whom collected 30 to 65 plants while spending 1 to 6 days in the Seven Devils, include:

1. Aven Nelson, whose field records and almost all of his 65 Seven Devils collections are at RM (B. E. Nelson 1983).
2. Quentin Jones, in 1950 working toward a masters degree at the Washington State College Department of Botany.
3. Arthur R. Kruckeberg, Department of Botany, University of Washington, who visited the Seven Devils twice, the second time (1952) leading a field trip of University of Washington students.

4. Marion Ownbey, later director of the WSC (now Ownbey) Herbarium, with Frederick Meyer and Hannah Aase, leading a 1940 WSC botany field trip.

5. Francis W. Pennell, monographer of the Scrophulariaceae, whose 1937 Black Lake area foray was chronicled by his field notes deposited at and obtained from the Philadelphia Academy of Natural Sciences (PH). Most of his Seven Devils collections remain there (Spawn 1983; Schuyler 1984). See table 1 for details on the Seven Devils collections of these five collectors.

Among the 31 remaining Seven Devils plant collectors, and aside from Bingham and Miller, only 10 have gathered from 10 to 29 collections. These collectors are Verne E. Comstock, a WSC agronomy student; Douglass M. Henderson, director, ID; Frederick J. Hermann of the Forest Service, whose personal herbarium recently was deposited at the University of Michigan Herbarium; Monta C. LaZelle, an herbarium assistant at ID, who started a Seven Devils flora; Frederick G. Meyer, then a WSC botany graduate student, who visited the Seven Devils in four different years with the natural history club and with Marion Ownbey; William R. Moore, a WSC forestry student, later husband of Jacqueline Packard, who also made many St. Joe National Forest plant collections while on summer work near Avery, ID; Gerald W. Munro, a WSC horticulture student; Don L. Peters, a WSC agriculture student; Edwin W. Tisdale, emeritus professor of range management at the College of Forestry, Wildlife and Range Sciences, University of Idaho, then establishing study plots for grassland habitat typing; and Charles A. Wellner, Forest Service, first chairman of the Idaho Natural Areas Council and largely responsible for establishment work on the proposed Little Granite Creek Research Natural Area, also the only person known to have collected atop Pollock Mountain. The details of the collections of these 10 collectors, along with those of the collections of the remaining 20 known Seven Devils collectors, will be found in table 1.

REFERENCES

Arnow, Lois A. *Poa secunda* Presl. versus *P. sandbergii* Vasey. (Poaceae). Systematic Botany. 6(4): 412-421, 1981.

Carrey, J.; Conley, C.; Barton, A. Snake River of Hells Canyon. Cambridge, ID: Backeddy Books; 1979. 399 p.

Davis, Hal W. [Personal communication.] 1983 November 29. Idaho Falls, ID.

Davis, Ray J. Flora of Idaho. Dubuque, IA: Wm. C. Brown Company; 1952. 836 p.

Deardorff, David C. Biosystematic studies in *Hieracium* (Asteraceae) Section Thyrsoidea. Seattle, WA: University of Washington; 1977; 358 p. Ph.D. thesis.

Dorn, Robert D. A systematic study of *Salix* Section Cordatae in North America. Canadian Journal of Botany. 53: 1491-1522; 1975.

Gardner, Pam. Digging for answers. Intermountain Reporter. Ogden, UT: U.S. Department of Agriculture, Forest Service; 1986 March-April; 8-9.

Gaston, M. P.; Bennett, E. H. Geologic map of the Grangeville Quadrangle, Idaho: 2° Quadrangles; Moscow, ID: Idaho Bureau of Mines and Geology; 1979 (rev.). 1 p.

Henderson, D. M.; Johnson, F. D.; Packard, P.; Steele, R. Endangered and threatened plants of Idaho. Bull. 21. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1977. 72 p.

Henderson, Lewis F. Early experiences of a botanist in the northwest. Corvallis, OR: University of Oregon Library; undated. 59 p. Unpublished manuscript.

Hibbs, Earl. [Personal conversation at Earl and Esther Hibbs' South Fork Palouse River Ranch.] 1984 April. Pullman, WA.

Hitchcock, C. L.; Cronquist, A. Flora of the Pacific Northwest; an illustrated manual. Seattle, WA: University of Washington Press; 1973. 730 p.

Hitchcock, C. L.; Cronquist, A.; Ownbey, M.; Thompson, J. W. Vascular plants of the Pacific Northwest. 5 parts. Seattle, WA: University of Washington Press; 1955-1971. [Parts specifically cited: Part 2. Salicaceae to Saxifragaceae. 597 p. 1964 (by Hitchcock and Cronquist); Part 3. Saxifragaceae to Ericaceae. 614 p. 1961 (by Hitchcock and Cronquist); Part 5. Compositae. 343 p. 1955 (by Cronquist).]

Holmgren, P. K. A biosystematic study of North American *Thlaspi montanum* and its allies. Memoirs New York Botanical Garden. 21(2): 1-106; 1971.

Holmgren, P. K.; Keuken, W.; Schofield, E. S., compilers. The herbaria of the world. Index Herbariorum Pt. 1, 7th ed. Boston, MA: W. Junk; 1981. 452 p.

Hooper, Peter R. The Columbia River basalts. Science. 215(4539): 1463-1468; 1982.

Kellogg, Elizabeth A. A biosystematic study of the *Poa secunda* complex. Cambridge, MA: Harvard University; 1983. 186 p. Ph.D. thesis.

Lenz, Lee W. [Personal communication.] 1983a October 25. Director, Rancho Santa Ana Botanic Garden, Claremont, CA.

Lenz, Lee W. [Personal communication.] 1983b December 13. Director, Rancho Santa Ana Botanic Garden, Claremont, CA.

Livingston, D. C. Certain topographic features of north-eastern Oregon and their relation to faulting. Journal of Geology. 36: 694-708; 1928.

Nelson, B. E. [Personal communication.] 1983 October and November. Herbarium Manager, Rocky Mountain Herbarium, University of Wyoming, Laramie, WY.

Pierson, Walter W. [Personal communication.] 1983 December 19. Branch Chief, Range, Wildlife, and Soil and Water Management, Payette National Forest, McCall, ID.

Schuyler, A. E. [Personal communication.] 1984 February 7. Associate Curator, Philadelphia Academy of Natural Sciences, Philadelphia, PA.

Smith, C. P. Species *Lupinorum* Paper 93. [Publisher unknown]; 1951: 691.

Spawn, C. M. [Personal communication.] 1983 November 30. Librarian, Philadelphia Academy of Natural Sciences, Philadelphia, PA.

St. John, Harold. Flora of southeastern Washington and of adjacent Idaho. Escondido, CA: Outdoor Pictures; 1937 (rev. 1956). 583 p.

St. John, Harold. [Letter of 18 October 1982.] 1982. On file in author's personal collection.

Steele, R.; Brunsfeld, S. J.; Henderson, D. M.; Holte, K. E.; Johnson, F. D.; Packard, P. L. Vascular plant species of concern in Idaho. Bulletin 34. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1981 (with 1983 supplement). 161 p. plus 20 additional p. in 1983 supplement.

Steele, R.; Pfister, R. D.; Ryker, R. A.; Kittams, J. A. Forest habitat types of central Idaho. General Technical Report INT-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 138 p.

Stieber, Michael T. Register of plant collector's field notes held in North American institutions. Huntia. 4(3): 151-202; 1982.

Tisdale, Edwin W. A preliminary classification of Snake River grasslands in Idaho. Note 32. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1979. 8 p.

Tisdale, Edwin W. Grasslands of western North America: the Pacific Northwest bunchgrass type. In: Nicholson, A. C.; McLean, A.; Baker, T. E., eds. Proceedings, grasslands ecology and classification symposium; 1982; Kamloops, BC. Victoria, BC: British Columbia Ministry of Forests; 1983: 223-245.

Wheeler, H. E.; Cook, E. F. Structural and stratigraphic significance of the Snake River capture, Idaho-Oregon. Journal of Geology. 62(6): 525-536; 1954.

Winward, H. H.; Tisdale, E. W. Taxonomy of the *Artemisia tridentata* complex in Idaho. Bulletin 19. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1977. 15 p.

CHECKLIST

Aceraceae

Acer glabrum Torr. var. *douglasii* (Hook.) Dippel, Douglas Maple.

Common, encircling entire Seven Devils and along lower Rapid River, 5,000-7,200'.

Bingham and Miller 562, ID and WS, Douglas-fir-Ninebark h.t. on dry, open, southeast-facing forest slope on lower McClinery Ridge, ca. 1 mi up rd. 517 from its 2d crossing of Papoose C in sec. 26, 5,150', 8/17/72.

Brewer 34, Council R.D., Patrolman Cr. (small creek north of Jackley Mt.), sec. 1, T. 22 N., R. 2 W., 6,000', 8/30/28.

Plus 31 Sight Records by Bingham and Miller and C. Johnson and Steele.

Anacardiaceae

Rhus glabra L., Smooth Sumac.

Scarce, lower Rapid River only, 2,300' ±.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 ca. ¼ mi above the trailhead gate at the southwest end of the Circle C State Fish Hatchery, 2,300', 6/8/82.

Rhus radicans L., Poison Oak or Ivy.

Scarce, lower Rapid River only, 2,200' ±.

Bingham and Miller Sight Record, at the trail 113 trailhead gate in the southwest corner of the Circle C State Fish Hatchery, 2,200', 6/8/82.

Apiaceae

Angelica arguta Nutt., Sharp tooth Angelica.

Scarce, central Seven Devils, 7,000' ±.

Brewer 38, Council R.D., Iron Springs Ranger Station (at the spring north of Holbrook Saddle), sec. 24, T. 22 N., R. 3 (?2) W., 6,500' (actually nearer 7,000'), 9/2/28.

Cymopteris terebinthinus Wats. var. *foeniculatus* (Torr. and Gray) Cronq., Turpentine Cymopteris.

Uncommon, central Seven Devils, 5,700-8,300'.

Bingham and Miller 78 and 388, ID, and 420, ID and WS, edge of open sedge meadow in valley ca. ½ mi directly north of the summit of He Devil Mt., 8,300', 7/25/79; south-facing rocky hillside in an open subalpine fir-lodgepole pine forest ca. ½ mi up Hanson Cr. from the Old Boise Trail, 7,300', 7/29/81 and flat, marshy area on the plateau at the very head of Bernard Cr. ca. ¼ mi southwestward along trail 112 from the jct. of trails 112, 140, and 57 at the Iron Phone, 7,400', 8/10/81; respectively.

Christ 12673, ID, on sliderock along the Sheep Cr. trail, 7/17/41.

*St. John and Mullen 8406, ?WS, vicinity of McGaffee Cow Camp, ? elev., 7/18/27.

Plus 4 Sight Records by Bingham and Miller: Dog Cr., Bridge Cr. below Mirror Lake, trail 123 just northwest of Lily Pad Lake, and shores of Bernard Lakes, 7,200-7,600'.

Heracleum lanatum Michx., Cow Parsnip.

Frequent, entire Seven Devils and Rapid River, 5,000-7,500'.

Bingham and Miller 262, ID, open north-facing slope protected by cliffs to south, rocky loam, along trail 112 ca. ½ mi west-northwest of the Windy Saddle trailhead, 7,200', 8/29/80.

Brewer 124, Council R.D., Lost Basin Cr., sec. 22, T. 21 N., R. 2 W., 7,500', 7/17/31.

Plus 10 Sight Records by Bingham and Miller, Cold Springs Lookout site to Rankin Mill, 5,850-7,300'.

?*Ligusticum filicinum* Wats., Fern-leaved Licorice-root.

*Christ 12639 and 12716, ?NY, bank of Sheep Cr. Lake No. 2 (Shelf Lake), 7/16/41; and in marsh, Sheep Cr. Swamp, 7/17/41; respectively (but range of this taxon is generally to the south and east of the Seven Devils, likely to be *L. tenuifolium* Wats.).

Ligusticum tenuifolium Wats., Slender-leaved Licorice-root.

Scarce, central and southern Seven Devils, 7,200-7,900' ±.

*Christ 8712, ?NY, under edges of huge rocks on slopes above Black Lake, 8/8/37.

*Taylor 1666, WWB, mountain meadow near snowline above Sheep Lake, 7,875' +, 9/17/67.

Lomatium ambiguum (Nutt.) Coult. and Rose, Swale Desert Parsley.

Scarce, northern Seven Devils, 5,100-5,700'.

Bingham 272, ID and WS, ca. 0.3 mi northwards along rd. 2060 from Meyer Cr., 5,720', 7/8/81.

Tisdale 7/13/78, IDF 78358, near Low Saddle in the upper Clark's Fork of Sheep Cr., 7/13/78.

Lomatium cous (Wats.) Coult. and Rose, Cous Biscuitroot.

Uncommon (mostly at lower elevs.), northern and central Seven Devils, 5,000-7,800'.

Baker 12281, ID, open, gravelly slopes west of Seven Devils Camp, 7/31/54.

Bingham 281, ID, and Bingham and Miller 507, ID and WS, on reddish, weathered basalt ca. 0.2 mi east-northeast across rd. 1819 from Cold Springs Cow Camp cabin, 6,620', 8/8/81; and along trail 104 at Big Canyon Saddle, 5,000', 6/11/82; respectively.

Christ 12487, ID, windswept, rocky ridge, Seven Devils Ridge, 7/11/41.

Munro 71, WS, ridge above McGaffee Cow Camp at head of Bernard Cr., 4,500' (but the Cow Camp is at 5,700'), 5/14/37.

Plus 3 Sight Records by Bingham and Miller, Cow Cr. Saddle to Cold Springs Lookout site, 5,000-6,800'.

Lomatium cusickii (Wats.) Coult. and Rose, Cusick's Desert Parsley.

Common, central and southern Seven Devils, 5,500-8,200'.

Baker 12279, ID, open, gravelly slopes west of Seven Devils Camp, 7/31/54.

Bingham and Miller 211, ID and WS, and Bingham 335, ID, along the Old Boise Trail 101 just north of the Horse Heaven Lookout cabin, 8,150', 8/25/80; and along trail 214 ca. 0.2 mi south of Purgatory Saddle, 7,800', 7/17/81; respectively.

*Christ 12649, ?NY, soil pockets on ridges between Sheep Cr. Lakes 3 and 4 (between Gem and Sheep Lakes), 7/16/41.

Christ 12486 and 12656, ID and WS, windswept ridge, Seven Devils Ridge, 7/11/71; and on talus slope above Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41; respectively.

Cusick 2228, WS, dry ridge near Peacock Mine (5 mi north-northeast of Cuprum at the head of the Copper Cr. fork of Deep Cr.), 7/11/1899 (flowers) and 9/5/1899 (prob. 9/15/99, fruits).

C. Johnson 8/30/83, BKR 2598, Joes Gap, 8,000', 8/30/83.

Q. Jones 228, WS, ¼ mi south of Heavens Gate Lookout, 7/13/50.

Meyer 1614, WS, east side of Sheep Cr. 2 mi from Snake River, 5,500', 5/12/39.

St. John and Mullen 8480, WS, Dry Diggins Ridge, 7,300', 7/20/27.

Plus 12 Sight Records by Bingham and Miller.

Lomatium dissectum (Nutt.) Math. var. *eatonii* (Coult. and Rose) Cronq., the long-pediciled and less finely leafleted variety of Fernleaf Desert Parsley.

Occasional, northern and central Seven Devils, 5,100-6,400'.

C. Johnson Sight Records, Plot 791, above rd. 2060 ca. ¼ mi west of Lost Valley Cr., 5,100', 6/29/82; Plot 792, above rd. 2060 just northeast of Lost Valley Cr., 5,200', 6/29/82; and Plot 7044, east of trail 214 ca. 1½ mi north of Emerald Lake, 6,400', 8/19/83.

Lomatium dissectum (Nutt.) Math. var. *multifidum* (Nutt.) Math. and Const., the long-pediciled and fine-leafleted variety of Fernleaf Desert Parsley.

Frequent (mostly at lower elevs.), entire Seven Devils and Rapid River, 5,000-7,800'.

Bingham and Miller 261 and 493, ID and WS, and 479, ID, along trail 112 in the talus slopes ca. ¼ mi east of the jct. of trails 112, 140 and 57 at the Iron Phone, 7,000', 8/29/80; along the lower Rapid River trail 113 across from the mouth of Blue Gulch, 2,400', 6/8/82 (flowers yellow); and along the lower Rapid River trail 113 ca. 1 mi above Blue Gulch, 2,600', 6/8/82 (flowers maroon); respectively.

*Christ 8613, ?NY, gravelly mountainside, Smith Mt., 8/8/37.

Plus 6 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle and Wild Horse Butte to Black Lake, 5,000-7,800'.

Lomatium grayi Coult. and Rose, Gray's Desert Parsley.

Occasional, northern and southern Seven Devils, 5,000-5,600'.

Christ 11076, ID and WS, mountainside in Snake River Gorge west of Cuprum, 5/30/40.

Lewis 2272, BOIS, OGDF, Steele Stand 72-Pa-24, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,700', 6/12/72.

Steele 114, BOIS, Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,130', 6/12/72.

C. Johnson Sight Record, Plot 793, below the rd. just southwest of Grave Point Lookout, 5,550', 6/29/82.

Steele Sight Record, Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,100', 6/12/72.

Lomatium nudicaule (Pursh) Coult. and Rose, Barestem Desert Parsley.

Occasional (on weathered basalt), central Seven Devils, 7,300-7,400'.

Bingham and Miller 418, ID and WS, on weathered Imnaha Basalt along trail 112 ca. ¼ mi south of its jct. with trails 140 and 57 at the Iron Phone, 7,400', 8/10/81.

Christ 12710, ID and WS, basalt scab outcrops near Lily Pad Lake, 7/17/41.

Lewis 2267, BOIS, OGDF, near Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72.

St. John and Mullen 8527, WS, dry gravel flat on Dry Diggins, 8,000', 7/22/27.

Plus 1 Sight Record by Bingham and Miller, basalt outcrops nort west of Lily Pad Lake, 7,300', 8/11/81.

Lomatium serpentinum (Jones) Math., Snake River Canyon Desert Parsley.

Occasional (mostly at lower elevs.), central and southern Seven Devil and Rapid River, 5,000-7,000'.

Bingham and Miller 485, ID and WS, ca. 1.1 mi up the lower Rapid River trail from the Circle C State Fish Hatchery trailhead gate, 2,350', 6/8/82.

Meyer 1615, WS, above the east side of Sheep Cr. 2 mi from the Snake River, 5,500', 5/12/39.

St. John and Mullen 8458, WS, Dry Diggins Ridge, 7,000', 7/20/27.

Bingham and Miller Sight Record, north end of rd. 106 at Sheep Rock, 6,800', 6/27/83.

Lomatium triternatum (Pursh) Coult. and Rose ssp. *triternatum* var. *anomalum* (Jones) Math., the broad-leaf-segmented variety of Nine-leaf Desert Parsley.

Uncommon, northern and southern Seven Devils, 5,000-6,400'.

Bingham and Miller 506, ID and WS, along trail 104 at Big Canyo Saddle, in *Festuca idahoensis* - *Agropyron spicatum* h.t., 5,000', 6/11/82.

Davis 2283, WS, dry ridge, Grave Point Lookout, 6/24/40.

C. Johnson 6/29/82, WS, Plot 793, below rd. just southwest of Grave Point Lookout, 5,550', 6/29/82.

Plus 2 Sight Records by Bingham and Miller and C. Johnson; sout of Lockwood Saddle, 6,400'; and above rd. 2060 ¼ mi west o Lost Valley Cr., 5,100'.

Lomatium triternatum (Pursh) Coult. and Rose ssp. *triternatum* var. *triternatum*, Nine-leaf Desert Parsley.

Occasional, central Seven Devils, 7,000-8,200'.

?Bingham and Miller 74, ID, edge of sedge meadow and *Pinus albicaulis* stand, valley ca. ½ mi directly north of the summit of He Devil Mt., 8,250', 7/25/79 (mature fruits absent).

Bingham and Miller 423, ID and WS, open forb meadow on north-facing rocky hillside, ca. ½ mi east of the jct. of trails 112 and 56 north-northeast of Hibbs Cow Camp, 7,400', 8/10/81.

Bingham and Miller Sight Record, along the north fork of Little Granite Cr. trail 112 ca. 2/3 mi south of Hibbs Cow Camp, 7,000', 8/11/81.

Lomatium triternatum (Pursh) Coult. and Rose ssp. and var. undet., Nineleaf Desert Parsley.

C. Johnson Sight Record, Plot 7076, east of the Heavens Gate Lookout rd. ca. 1/3 mi south of the lookout parking area, 7,930', 9/2/83.

Osmorhiza chilensis Hook. and Arnott, Mountain Sweet Cicely.

Common, entire Seven Devils, 5,100-7,600'.

Baker 12255, ID, moist woods along Shingle Cr. (along rd. 517), 7/31/54.

Christ 12686, WS, timbered slopes along the Sheep Cr. trail, 7/17/41.

C. Johnson 6/29/82, BKR 2034, Plot 789, above rd. 2060 ca. ¼ mi, east of Kirkwood Cr., 5,220', 6/29/82.

Plus 17 Sight Records by C. Johnson, Kirkwood Cr. to Black Lake, 5,200-7,600'.

Osmorhiza occidentalis (Nutt.) Torr., Western Sweet Cicely.

Common, entire Seven Devils, 5,000-7,800'.

Baker 12056, ID, open alpine slopes near Seven Devils Camp, 7/21/54.

Bingham and Miller 140, ID and WS, open, east-facing, rocky slope protected by edge of boulderfield to south and edge of *Abies lasiocarpa, Pinus albicaulis, Picea engelmannii* forest to north, along the south side of Dog Cr. ca. 3/5 mi below the Lake, 7,500', 7/16/80.

Brewer 108, Council R.D., Granite Cr. (? Granite fork of the Lake fork of the Rapid River), sec. 10, T. 22 N. (? 21 N.), R. 3 W. (? 2 W.), 8/1/30.

*Christ 12528, ?NY, open, grassy east slopes, Heavens Gate, 7/12/41.

St. John and Mullen 8388, WS, in thicket, McGaffee Cow Camp, 5,400', 7/17/27.

Plus 28 Sight Records by Bingham and Miller and C. Johnson, including vicinities of Big Canyon Saddle, Cold Springs Lookout, and China Saddle.

Osmorhiza purpurea (Coult. and Rose) Suksd., Purple Sweet Cicely.

Uncommon, central Seven Devils and west Fk. of Rapid River, 6,800-7,600'.

Bingham and Miller 128 and 167, ID and WS, streambottom under dense, closed forest of *Picea engelmannii, Abies lasiocarpa* and *Pseudotsuga menziesii*, just above the Old Boise Trail 101 at Hanson Cr., 6,800', 7/16/80; and streambottom under moderately dense *Abies lasiocarpa, Picea engelmannii* forest, bottom of Hanson Cr. ca. ¼ mi below the Old Boise Trail 101, 6,750', 7/17/80; respectively.

Christ 12671, ID, on sliderock slopes with Douglas-fir, Sheep Cr., 7/17/41.

Plus 6 Sight Records by Bingham and Miller; McGaffee Cow Camp to Stevens Saddle, 6,800-7,600', and west fork Rapid River.

Perideridia bolanderi (Gray) Nels. and Macbr., Bolander's Yampa.

Uncommon, central and southern Seven Devils, 5,100-7,300'.

?Bingham and Miller 430, ID, west-facing rocky slope in an open forb-sedge stand at the edge of a *Pinus contorta-Abies lasiocarpa* forest, along the Dry Diggins Ridge trail 140 just north of its jct. with trails 112 and 57 at the Iron Phone, 7,360', 8/12/81 (flowers white but fruits immature).

Kruckeberg 3199, WS, WTU, dry, open outcrops along flats of Dry Diggins area (prob. along trail 112), 7,000', 8/1/52.

Packard 426, WS, dry, rocky flat near Lily Pad Lake, 7,800' (but lake elev. is 7,300'), 7/22-23/38.

St. John and Mullen 8470, WS, gravel slope, Dry Diggins, 7,000', 7/20/27.

Plus 4 Sight Records by Bingham and Miller and Steele (including one from the Bear-Indian Crs. divide along rd. 002).

Perideridia gairdneri (Hook. and Arnott) Math. var. *borealis* Chuang and Const., Gairdner's Yampa.

Scarce, northern and central Seven Devils, 5,200-7,300' ±.

*Christ 12621, ?NY, on andesite knolls of dissected plateau, Hibbs Cow Camp, 7/15/41.

C. Johnson Sight Record, Plot 792, above rd. 2060 just northeast of Lost Valley Cr., 5,220', 6/29/82.

Apocynaceae

Apocynum androsaemifolium L. var. *pumilum* Gray, Spreading Dogbane.

Frequent, central Seven Devils and Rapid River, 5,000-8,000'.

Bingham and Miller 434, ID and WS, northeast shore of Quad Lake, 7,350', 8/14/81.

Packard 329, WS, slope above McGaffee Cow Camp, 4,800' (but Camp is at 5,700'), 6/29/37.

Plus 8 Sight Records by Bingham and Miller and C. Johnson, McGaffee Cow Camp to Ruth Lake, 6,200-8,000'.

Asclepiadaceae

Asclepias speciosa Torr., Showy Milkweed.

Scarce, lower Rapid River, 2,200' ±.

Bingham and Miller Sight Record, open grass-forb slope along the lower Rapid River trail 113 ca. 0.1 mi above the trailhead gate at the Circle C State Fish Hatchery, 2,250', 6/8/82.

Asteraceae

Achillea millefolium L. ssp. *lanulosa* (Nutt.) Piper, the Inland Northwest subspecies of Yarrow.

Abundant, one of the Seven Devils' 10 most common plants, ubiquitous from the lower Rapid River to peaks under 8,800'.

Baker 12022, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 148, ID and WS, *Carex hoodii/Festuca idahoensis* h.t. in a forest opening just northwest of the Old Boise Trail 101 at Hanson Cr., 6,800', 7/17/80.

Brewer 75, IDF, level, gravelly meadow, Paradise Flat (in the head of Paradise Cr. off the Rapid River and ca. ½ mi west of the old Iron Springs townsite northeast of Black Lake), 6,000', 8/2/29.

*Christ 12443, ?NY, talus slopes above Seven Devils Lake, 7/11/41.

Plus 80 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Adenocaulon bicolor Hook., Trail Plant.

Uncommon, entire Seven Devils, 5,000-6,700'.

Bingham and Miller 590B and 603, ID and WS, bottom of the eastmost small fork of Shingle Cr., bordering a Douglas-fir/Ninebark clearcut, on lower McClinery Ridge ca. ½ mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, 4,900', 8/17/82; and in a Douglas-fir/Ninebark forest along the east fork Sheep Cr. trail 58 just east of ¼ sec. Corner 36/31, 5,850', 8/18/82; respectively.

Plus 4 Sight Records by C. Johnson and Steele, Kirkwood Cr. to Landore, 5,000-6,700'.

Agoseris aurantiaca (Hook.) Greene var. *aurantiaca*, Orange False Dandelion.

Common, central Seven Devils, 6,800-7,900'.

Baker 12270, ID, dry, gravelly hillside on west slope of Heavens Gate, 7/31/54.

Bingham and Miller 153, ID and WS, *Carex hoodii/Festuca idahoensis* h.t. in meadow below the Old Boise Trail 101 just northeast of Hanson Cr., 6,800', 7/17/80.

*St. John and Mullen 8472, ?WS, Dry Diggins Area, 7/20/27.

Plus 17 Sight Records by Bingham and Miller.

?Agoseris glauca (Pursh) Raf. var. *agrestis* (Osterh.) Q. Jones, the lanceolate-leaved, pinkish-involucral-bracted variety of the Pale False Dandelion (usually from much lower elev. than the collection and sight record below).

Baker 12084, ID, dry, gravelly soil on a point above Seven Devils Guard Station, 7/21/54.

C. Johnson Sight Record, Plot 7021, east of trail 124 ca. 1 mi south of Hibbs Cow Camp, 7,050', 8/11/83.

Agoseris glauca (Pursh) Raf. var. *dasycephala* (Torr. and Gray) Jeps., the oblanceolate-leaved variety of the Pale False Dandelion.

Scarce, central and southern Seven Devils, 5,000-6,800'.

Bingham and Miller 612, ID and WS, in an open *Pseudotsuga menziesii, Abies lasiocarpa, Pinus contorta, Pinus albicaulis* forest near the start of the Sheep Rock Nature Trail at the north end of rd. 106, 6,800', 7/27/83.

*St. John and Mullen 8614, ?WS, along Squaw Cr. (above Papoose Cr. on this Little Salmon River tributary), ? elev., 7/27/27.

Agoseris glauca (Pursh) Raf. intermediate between vars. *dasycephala* (Torr. and Gray) Jeps., *laciniata* (Eat.) Smiley and *monticola* (Greene) Q. Jones, Pale False Dandelion.

Uncommon, entire Seven Devils and Rapid River, 5,000-8,100'.

Bingham and Miller 210, ID and WS, and 390, ID, exposed, subalpine, sedge-forb meadow in the immediate vicinity of the Horse Heaven Lookout cabin, 8,100', 8/25/80; and in an open *Pseudotsuga menziesii* forest ca. 0.1 mi up the Cannon Lake trail from the Old Boise Trail, 6,500', 7/27/81; respectively.

Plus 7 Sight Records by Bingham and Miller, Big Canyon Saddle to Lockwood Saddle, 5,000-7,600'.

Agoseris glauca (Pursh) Raf. var. *monticola* (Greene) Q. Jones, the lanceolate-leaved variety of the Pale False Dandelion.

Scarce, northern Seven Devils, 5,100-5,300'.

C. Johnson Sight Records, Plot 781, in an *Agropyron spicatum/Festuca idahoensis* community on the Table Lands ca. ¼ mi south-southeast of Dixon Corrals, 5,150', 6/25/82; and Plot 786, in a *Festuca idahoensis/Koeleria cristata* community ½ mi down Caribou Cr. from rd. 2060 and just north of the cr., 5,260', 6/27/82.

Agoseris glauca (Pursh) Raf. var. undet., Pale False Dandelion.

5 Sight Records by C. Johnson, Fire Camp Saddle to Horse Heaven Lookout pasture, 5,900-8,070', 8/10/83-9/1/83.

Agoseris grandiflora (Nutt.) Greene, large-flowered False Dandelion.

Scarce, northern Seven Devils, prob. mostly below 5,000'.

Tisdale Sight Record, vicinity of Low Saddle, 5,200', 7/13/78.

Agoseris heterophylla (Nutt.) Greene var. *heterophylla*, Annual Agoseris.

Scarce (mostly from lower elevs.), central Seven Devils, 5,000' ±.

*St. John and Mullen 8602, ?WS, along Sheep Cr. (prob. on trail 110), ? elev., 7/26/27.

Anaphalis margaritacea (L.) Benth. and Hook., Pearly Everlasting.

Common, entire Seven Devils, 5,000-8,000'.

Baird 7/29/71, Council R.D., in timber ½ mi down rd. (108) from Horse Mt. Lookout, 6,900', 7/29/71.

Baker 11301 and 12063, ID, summit of Sheep Rock, 6,850', 9/3/53; and open, wooded slopes above Seven Devils Guard Station, 7/21/54; respectively.

Bingham and Miller 233, ID and WS, moderately dense *Abies lasiocarpa* forest on bench along the Ruth Lake trail ca. 0.1 mi east of the lake, 7,200', 8/27/80.

Plus 32 Sight Records by Bingham and Miller, C. Johnson and Steele, Cold Springs to Kinney Point, 5,000-7,800'.

Antennaria alpina (L.) Gaertn. var. media (Greene) Jeps., Alpine Everlasting.

Uncommon, central and southern Seven Devils, 6,800-8,000' +.

Baker 11309, ID, moist, shaded slope, Sheep Rock, 9/3/53.

*Christ 8617 and 12444, ?NY, high, open mountainside, Smith Mt., 8/8/37; and talus slopes above Seven Devils Lake, 7/11/41; respectively.

C. Johnson 8/14/83, BKR 2480, Plot 7037, east of the Old Boise Trail 101 ca. 1/3 mi southwest of Papoose Lake, *Pinus albicaulis/Luzula hitchcockii* and *Juncus parviflora* community, 7,980', 8/14/83.

St. John and Mullen 8572, WS, forming mats on rocky ledge, He Devil Mt., 9,000', 7/24/27.

Antennaria anaphaloides Rydb., Tall Everlasting.

Uncommon, northern and central Seven Devils, 6,700-8,400'.

*Christ 12571, ?NY, grassy west slopes, Heavens Gate, 7/12/41.

Davis 2355, WS, medium dry hillside, Heavens Gate, 6/28/40.

C. Johnson 9/2/83, BKR 2430, Plot 7076, east of the Heavens Gate Lookout rd. ca. 1/3 mi south of the parking area for the Lookout, *Festuca idahoensis/Phlox diffusa* community, 7,930', 9/2/83.

Q. Jones 212, WS, vicinity of Heavens Gate Lookout, 7/12/50.

Tisdale 7/11/79, IDF 81131, 1½ mi west of Cold Springs Lookout, 6,700', 7/11/79.

Antennaria lanata (Hook.) Greene, Woolly Everlasting.

Uncommon, central and southern Seven Devils, 7,600-8,400'.

*Baker 12030, ?ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 22, ID, along the trail from the Heavens Gate parking lot to the Lookout, in an open *Abies lasiocarpa-Pinus albicaulis* stand, 8,300', 7/21/79.

*Christ 8708, ?NY, grassed talus slopes near Black Lake, 8/8/37.

C. Johnson 8/14/83, BKR 2478, Plot 7037, east of the Old Boise Trail 101 ca. 1/3 mi southwest of Papoose Lake, *Pinus albicaulis/Luzula hitchcockii* and *Juncus parviflora* community, 7,980', 8/14/83.

Steele 938, BOIS and ID, just below Heavens Gate, 8/8/74.

Plus 1 Sight Record by Bingham and Miller.

Antennaria luzuloides Torr. and Gray, Woodrush Everlasting.

Occasional, entire Seven Devils, 5,700-7,400'.

Aldrich 7/4/07, ID 7824, Camp Howard, 7/4/07.

Bingham 309, ID, on open, weathered, reddish basalt east-northeast across rd. 1819 from Cold Springs Cow Camp, 6,620', 7/10/81.

Brewer 63, Council R.D., Huntley Spring, sec. 14, T. 20 N., R. 3 W., 5,000', 7/1/29.

Steele 83, BOIS, Steele Stand 72-Pa-25, Bear-Indian Crs. divide, sec. 28, T. 20 N., R. 3 W., 5,130', 6/12/72.

Plus 2 Sight Records by C. Johnson and Steele, Dry Diggins Ridge trail 140 and Bear-Indian Crs. divide.

Antennaria microphylla Rydb., Rosy Everlasting.

Abundant, Camp Howard to Lockwood Saddle, 5,000-8,000'.

Aldrich 7/4/07, ID 7798, Camp Howard (prob. the Cow Camp), 5,000', 7/4/07.

Baird 7/29/71, Council R.D., open ridge at trailhead to Horse Heaven (? jct. trails 214 and 218), 7,500', 7/29/71.

Baker 12018 and 12058, ID, both open gravelly slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 127, 392, and 404, ID, small open meadow along the Old Boise Trail 101 just northeast of Hanson Cr., 6,800', 7/16/80; in the Cannon Lake burn ca. ½ mi up the Cannon Lake trail from the Old Boise Trail 101, 6,800', 7/22/81; and in a *Pseudotsuga menziesii* forest on a southeast-facing slope along the Old Boise Trail 101 ca. 0.1 mi north of the Cannon Lake trail, 6,500', 7/26/81; respectively.

Henderson and Bingham 3865, ID, east shore of Baldy Lake, 7/16/77.

C. Johnson 8/10/83 and 8/30/83 (2 colls.), BKR 2475, 2589 and 2590, Plot 7014, above trail 124 ca. ¼ mi south of the summit of Potato Hill, *Festuca idahoensis-Carex hoodii* h.t. 7,150', 8/10/83; Plot 7062, north of trail 217 at the southwest end of the 2d lake west-northwest trail, *Artemisia tridentata-Carex geyeri* community 7,360', 8/30/83; and Plot 7064, east of trail 217 in Horse Pasture Basin ca. ¼ mi southeast of Joes Gap, fire succession community, 7,620', 8/30/83.

St. John and Mullen 8510, WS, rock cliffs, Dry Diggins Area, 8,000', 7/21/27.

Tisdale 7/17/79, IDF 80176, subalpine grassland, Seven Devils Guard Station pasture, 7,500', 7/17/79.

Plus 36 Sight Records by Bingham and Miller and C. Johnson.

Antennaria racemosa Hook., Raceme Everlasting.

Common, northern and central Seven Devils and in Rapid River, 5,000-7,300'.

Baker 1200C, ID, moist grassy bank, wooded slope, 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 6/21/40.

Bingham and Miller 171 (male plants) and 172 (female plants), ID and WS, along the Old Boise Trail 101 ca. ¼ mi south of Cannon Cr., 7,100', 7/18/80 (both collections from same locality and population).

*Christ 12582, ?NY, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Henderson and Bingham 3865, ID, east shore of Baldy Lake, 7/6/77.

Q. Jones 230, ID and WS, 4 mi toward Riggins from Heavens Gate (prob. from Windy Saddle along rd. 517 near the top of McClinery Ridge), 7/14/50.

Plus 15 Sight Records by Bingham and Miller, C. Johnson and Steele.

Antennaria umbrinella Rydb., Umber Everlasting.

Frequent, central and southern Seven Devils, 6,900-9,000'.

Bingham and Miller 91 and Bingham 333, ID, open southeast-facing ridgetop with a loose gravelly rocky soil along northwest ridge off He Devil Mt., 9,000', 7/26/79; and open lake shore northwest shore of Black Lake, 7,200', 7/17/81; respectively.

Tisdale 7/17/79, IDF 80178, subalpine grassland, Seven Devils Guard Station pasture, 7,500', 7/17/79.

Plus 10 Sight Records by Bingham and Miller, Bernard Lakes to Horse Mt. Lookout, 7,200-8,100'.

Anthemis cotula L., Stinking Mayweed (European introduction).

Scarce, lower Rapid River, 2,200' ±.

Bingham and Miller 530, ID and WS, gate trailhead of trail 113 at the Circle C State Fish Hatchery, 2,200', 7/1/82.

Arctium minus (Hill) Bernh., Common Burdock (European introduction).

Occasional, lower, northern Seven Devils and Rapid River, 5,000-5,900'.

Bingham and Miller Sight Records, vicinity of Sawpit Saddle, 5,050', 7/8/81; near the jct. of rds. 1819 and 2060 ca. 1/3 mi east of Low Saddle, 5,900', 7/10/81; along rd. 672 south of Grave Point, 5,000', and near the lower Rapid River trail 113 trailhead at the Circle C State Fish Hatchery gate, 2,200', 6/8/82.

Arnica cordifolia Hook. var. *cordifolia*, Heart-leaf Arnica.

Abundant, entire Seven Devils and Rapid River, 5,000-7,800' (undoubtedly the most common Seven Devils plant, 85 occurrences noted).

Baird 6/26/72, Council R.D., on rd. to Black Lake (112), ? elev., 6/26/72.

Baker 12271, ID, dry, gravelly hillside on west slope of Heavens Gate, 7/31/54.

Bingham and Miller 158, ID, opening in dense *Abies lasiocarpa*/*Picea engelmannii* forest, bottom of Hanson Cr. just below the Old Boise Trail 101, 6,700', 7/17/80.

*Christ 12472, ?NY, slopes of Seven Devils Ridge, 7/11/41.

Christ 12542, ID, ledges on peak Heavens Gate, 7/12/41.

Davis 2319, WS, Bernard Lakes, 6/26/40.

LaZelle 5, ID, along rd. in Seven Devils Campground, 7,500', 8/29/63.

St. John and Mullen 8550, WS, rockslide on He Devil Mt., 9,000', 7/24/27.

Plus 78 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Huntley Gulch, 5,000-7,800'.

Arnica diversifolia Greene, Sticky Arnica.

Occasional, central Seven Devils, 7,600-7,800'.

Christ 12585, ID and WS, and 12640, ID, cirque below Seven Devils Lake, 7/13/41; and stream connecting Sheep Lakes 2 and 3 (west fork of west fork of Sheep Cr. between Shelf and Gem Lakes), 7/16/41; respectively.

Kruckeberg 3194, ID, WS, WTU, on talus and in crevices above Sheep Lake No. 2 (Shelf Lake), 7,500', 7/31/52.

Arnica fulgens Pursh, Orange or Hillside Arnica.

Uncommon, northern Seven Devils, 5,000-8,000'.

Aldrich 7/4/07, ID, Camp Howard (prob. the Cow Camp), 7/4/07.

Bingham 275, ID, and Bingham and Miller 385, ID and WS, *Festuca idahoensis/Koeleria cristata* grassland at Sawpit Saddle, 5,050', 7/8/81; and *Carex hoodii/Festuca idahoensis* grassland, northwest slopes of Bald Mt., 8,000', 7/30/81; respectively.

Tisdale 7/11/79, IDF 80182, 1½ mi west of Cold Springs Lookout, 6,600', 7/11/79.

Plus 3 Sight Records by Bingham and Miller.

Arnica latifolia Bong. var. *gracilis* (Rydb.) Cronq., the small variety of Mountain Arnica.

Common, entire Seven Devils, 6,500-8,300'.

Bingham and Miller 81, 375, and 406, ID, in an *Abies lasiocarpa/Pinus albicaulis* forest on the rocky ridge along trail 123 between Gem and Sheep Lakes, 8,250', 7/25/79; open Douglas-fir forest ca. 0.1 mi up the Cannon Lake trail from the Old Boise Trail 101, 6,500', 7/27/81; and open, northeast-facing cliffs along trail 112 ca. ½ mi west of Windy Saddle trailhead, 7,050', 8/10/81; respectivel

Christ 12441, 12467, and 12547, ID, and 12476, ID and WS, moraine ridges adjacent to Seven Devils Lake, 7/11/41; rock crevices in lee of cliff, Seven Devils Ridge, 7/11/41; slopes of Seve Devils Ridge, 7/12/41; and north face of peak, Heavens Gate, 7/11/41; respectively.

Davis 2325, WS, Sheep Cr., 6/26/40.

Henderson 3854, ID, Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7,500', 7/6/77.

Plus 15 Sight Records by Bingham and Miller, Heavens Gate to Kinney Point, 6,800-8,100'.

?*Arnica latifolia* Bong. var. *latifolia*, Mountain Arnica (usually found at lower elevs.).

C. Johnson 8/12/83, BKR 2565, Plot 7026, east of trail 56 ca. ¼ mi southwest of the largest Bernard Lake, 7,740', 8/12/83.

Arnica latifolia Bong. var. undet., Mountain Arnica.

1 Steele Sight Record.

Arnica longifolia D. C. Eat., Seep-spring Arnica.

Scarce, central Seven Devils, 7,700' ±.

Bingham and Miller 351, ID and WS, open, east-facing stream bottom of the Mirror Lake Fk. of Bridge Cr., ca. ¼ mi below the Lake, 7,700', 7/26/81.

*Nelson and Nelson 2978, ?RM, Dry Diggins Camp, 8/10-15/38.

Arnica mollis Hook., Hairy Arnica.

Frequent, central and southern Seven Devils, 6,500-8,400'.

Bingham and Miller 354, ID and WS, in an *Abies lasiocarpa/Picea engelmannii* forest bordering the perched marsh in the Mirror Lake Fk. of Bridge Cr. ca. ½ mi below the lake, 7,300', 7/26/81.

*Christ 8698, ?NY, high slopes and ridges near Black Lake, 7/7/37.

Christ 12552, ID, in lee of rocks on ridge, Heavens Gate, 7/12/41.

Plus 15 Sight Records by Bingham and Miller and C. Johnson, Dry Diggins Ridge to Joes Gap, 6,500-8,200'.

Arnica parryi Gray var. *parryi*, Nodding Arnica.

Uncommon, central Seven Devils, 7,000-8,000' (mostly restricted to the area within a few miles of Hibbs Cow Camp, with an outlier near Stevens Saddle).

Bingham and Miller 425, ID and WS, forb-grass meadow in open forest, along Dry Diggins Lookout trail 56 ca. ¼ mi north of trail 112, 7,600', 8/11/81.

C. Johnson 8/12/83, BKR ?2469, Plot 7025, west of trail 56 ca. ¼ mi south-southeast of Three Cr. Point, *Abies lasiocarpa/ Vaccinium scoparium* community, 7,900', 8/12/83.

Plus 7 Sight Records by Bingham and Miller, south end of Dry Diggins Ridge, Echo Lake trail 129, just south of Hibbs Cow Camp, trail 123 between Lily Pad and Basin Lakes, just north of Stevens Saddle, near jct. trails 112 and 56, and along trail 124 ½ mi south of Hibbs Cow Camp, 7,000-7,600'.

Arnica rydbergii Greene, Subalpine Arnica.

Scarce, central Seven Devils, 7,400-7,600'.

Baker 12282, ID, open, gravelly slopes west of Seven Devils Camp, 7/31/54.

Christ 12616, ID, on promontory jutting into Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41.

Arnica sororia Greene, Twin Arnica.

Uncommon, northern Seven Devils, 5,100-7,200'.

Bingham 540, ID and WS, open grass-forb stand along rd. 420 ca. 0.1 mi south of Cow Cr. Saddle, 5,240', 7/21/82.

Plus 4 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Dixon Corrals to Fire Camp Saddle, 5,100-7,200'.

?*Arnica ventorum* Greene (not known from Pacific Northwest).

*Nelson and Nelson 2985, RM, Horse Heaven, 8/10-15/38.

Artemisia ludoviciana Nutt. var. *incompta* (Nutt.) Cronq., the high-elevation variety of Louisiana Sage.

Common, northern and central Seven Devils and Rapid River, 5,000-7,900'.

Bingham and Miller 252, ID and WS, very rocky, open, grass-forb slope, along trail 124 at the north end of the switchbacks in the head of the south fork of Devils Farm Cr. ca. 3/4 mi north of Horse Heaven Saddle, 7,800', 8/28/80.

Plus 21 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to north of Emerald Lake, 5,000-7,900'.

Artemisia michauxiana Bess., Michaux Mugwort.

Occasional, central and southern Seven Devils, 7,000-7,200'.

Baird 9/8/71, Council R.D., at Sheep Rock point, 6,850', 9/8/71.

Baker 11294, ID, rocky slopes, summit of Kinney Point, 9/3/53.

*Nelson and Nelson 3023, ?RM, near rockslide, Dry Diggins trail, 7/10-15/38.

St. John and Mullen 8490, WS, rocky ridge, Dry Diggins, 7,000', 7/20/27.

Artemisia rigida (Nutt.) Gray, Rigid Sagebrush.

Occasional, northern and southern Seven Devils, at lower elevs., 5,000-5,300'.

Bingham 273, ID, open, basaltic ridgetop with grass-forb-sagebrush stand immediately north of the forks of rds. 420 and 672 at Cow Cr. Saddle, 5,260', 7/8/81 (as host of *Orobanche fasciculata*).

Lewis 2269b, BOIS, OGDF, near Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,700', 6/12/72.

Plus 3 Sight Records by Bingham and Miller and Steele, Big Canyon Saddle to Bear-Indian Crs. divide along rd. 002, 5,000-5,200'.

Artemisia tridentata Nutt. var. *vaseyana* (Rydb.) Beetle, the montane variety of Big Sagebrush.

Common, entire Seven Devils, 5,000-8,000'.

Bingham and Miller 169 and 245, ID and WS, east-facing, rocky, grass-sedge-sagebrush slope, between Bridge and Cannon Crs. along the Old Boise Trail 101, 6,800', 7/18/80; and southwest-facing, rocky grass-sagebrush slope, just northwest of Stevens Saddle along trail 192, 7,600', 7/27/80; respectively.

*Christ 8682, ?NY, highest ridges near Black Lake, 7/7/37.

Packard 343, WS, open, dry ridgetops, Potato Hill, 6/13-30/37.

St. John and Mullen 8529, WS, gravelly ridge, Dry Diggins, 7/22/27.

Plus 21 Sight Records by Bingham and Miller and C. Johnson.

Aster alpigenus (Torr. and Gray) Gray var. *haydenii* (Porter) Cronq., the Rocky Mountain variety of the Alpine Aster.

Scarce, central Seven Devils, 7,800' ±.

*Christ 12643, ?NY, small, grassy "lake" in talus, Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41.

Aster conspicuous Lindl., Showy Aster.

Uncommon, entire Seven Devils, 5,000-6,400'.

Baker 11338, ID, open, shaded woods 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

St. John and Mullen 8435, WS, rocky, ridge, McGaffee Cow Camp, 5,500', 7/19/27.

Plus 7 questionable Sight Records by C. Johnson and 2 Sight Records by Steele, Lost Valley Cr. to Bear-Cuprum rd. 002, 5,000-6,400'.

Aster foliaceus Lindl. var. *canbyi* Gray, the dry-site variety of the Leafy-bracted Aster.

Common, entire Seven Devils, 5,200-8,200'.

Bingham and Miller 207, ID and WS, subalpine grassland, immediate vicinity of Horse Heaven Lookout cabin, 8,200', 8/25/80.

Brewer 36, Council R.D., Iron Springs Ranger Station, 6,500', 9/3/28.

*Christ 8645, ?NY, timbered slopes surrounding Black Lake, 7/7/37.

Kruckeberg 2335, ID and WTU, end of rd. from Riggins (then at Windy Saddle), 8/25/51.

*Nelson and Nelson 2975 and 2988, ?RM, Dry Diggins Camp, and Horse Heaven, respectively, 8/10-15/38.

Plus 28 Sight Records by Bingham and Miller, Cow Cr. Saddle to Black Lake, 5,200-8,000'.

Aster foliaceus Lindl. var. *cusickii* (Gray) Cronq., the Wallowa Mountains variety of the Leafy-bracted Aster.

Scarce, central Seven Devils, 8,000' ±.

Baird 9/8/71, Council R.D., Towsley Spring (along rd. 106), 7,000', 9/8/71.

Baker 12266, ID, dry, gravelly west slope of Heavens Gate, 7/31/54.

Simon 8/28/84 and 8/29/84, BKR, C. Johnson Plot 7012, above trail 124 on Haas Flat ca. ½ mi north of Horse Heaven Saddle, 8,070', 8/28/84; and C. Johnson Plot 7009, above trail 101 southeast of Haas Lake overlooking Mill Cr. 7,350', 8/29/84; respectively.

Aster foliaceus Lindl. var. *lyallii* (Gray) Cronq., the tall variety of the Leafy-bracted Aster.

Uncommon, central Seven Devils, 7,000-8,100'.

Bingham and Miller 236, ID and WS, bordering a small marsh in an *Abies lasiocarpa* stand along the Ruth Lake trail ca. 0.1 mi east of the lake, 7,200', 8/27/80.

C. Johnson 8/10/83, BKR ?2469, Plot 7011, Horse Heaven Lookout pasture west of trail 101, *Festuca idahoensis-Carex hoodii* community, 8,040', 8/10/83.

Plus 3 Sight Records by Bingham and Miller and C. Johnson, Horse Heaven Cr., Haas Flat, and Windy Saddle, 7,000-8,100'.

Aster foliaceus Lindl. var. *parryi* (Eat.) Gray, Parry's Aster or the glabrous variety of the Leafy-bracted Aster.

Scarce, northern Seven Devils, 5,600' ±.

Bingham 558, ID and WS, ridgetop grass-forb-sedge stand ca. 150' northeast of the Grave Point Lookout tower, 5,530', 7/21/82.

Aster foliaceus Lindl. var. undet., Leafy-bracted Aster.

*Christ 8704, ?NY, lower slopes among trees near Black Lake, 8/8/37.

Plus 4 Sight Records by Bingham and Miller and Tisdale.

Aster integrifolius Nutt., Entire-leaved Aster.

Common, central and high southern Seven Devils, 6,500-8,000'.

Baker 11315 and 11335, ID, grassy, open meadow, Kinney Point, 9/3/54; and 6 mi north of Cuprum (prob. along rd. 106), 9/3/53; respectively.

Bingham and Miller 206 and 221, ID and WS, sedge-forb meadow on rocky ridgetop in forest opening, immediate vicinity of Horse Heaven Lookout cabin, 8,200', 8/25/80; and on north-facing talus at the west edge of the Horse Heaven Lookout pasture ca. ¼ mi southwest of the Lookout cabin, 8,000', 8/25/80; respectively.

*Christ 8611, ?NY, high, open mountainside, Smith Mt., 8/8/37.

Hibbs 8/17/37, WS 107757, ridge above "The Swamps," Dry Diggins area, 7,400', 8/17/37.

LaZelle 21, ID, on gravelly soil along the rd. ¼ mi east of Seven Devils Campground, 7,500', 8/29/63.

*Nelson and Nelson 3002, ?RM, Dry Diggins Lookout, 8/10-15/38.

Packard 433, WS, low ridge above the Swamps, Dry Diggins area, 7,400', 7/24/38.

Simon 8/24/84 and 8/28/84, BKR and C. Johnson Plot 7011, 200' west of trail 101 in Horse Heaven Lookout pasture, 8,040', 8/24/84; and C. Johnson Plot 7012, above trail 124 in Haas Flat ca. ½ mi north of Horse Heaven Saddle, 8,070', 8/28/84; respectively.

Plus 29 Sight Records by Bingham and Miller and C. Johnson.

Aster perelegans Nels. and Macbr., Elegant Aster.

Occasional, central and southern Seven Devils, 5,000-7,000'.

Baker 11333, ID, open wooded slope above spring, 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham and Miller 598, ID and WS, open *Pinus ponderosa* forest, prob. Douglas-fir/Ninebark h.t., on lower McClinery Ridge along rd. 517 ca. 1 mi above its 2d crossing of main Papoose Cr. in sec. 26, 5,150', 8/17/82.

C. Johnson 8/19/83, BKR 2045, Plot 7045, east of trail 214 ca. ½ mi south of Stevens Saddle, 6,900', 8/19/83.

Balsamorhiza incana Nutt., Hoary Balsamroot.

Scarce, northern Seven Devils, 5,200-5,600'.

Bingham 457, ID and WS, open, basaltic ridgetop with a grass-forb stand immediately south of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82 (growing alongside *B. sagittata*, may be a hybrid).

C. Johnson Sight Record, Plot 793, just southwest of Grave Point Lookout, 5,550', 6/29/82.

Balsamorhiza sagittata (Pursh) Nutt., Arrowleaf Balsamroot.

Common, entire Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller 181, ID, open Douglas-fir stand on rocky east-facing slope along the Old Boise Trail ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

Q. Jones 192, ID and WS, vicinity of Heavens Gate Lookout, 7/11/50.

Moore 73, WS, rocky hillside along Bernard Cr. trail (110) 3 mi from Snake River, 5,000', 5/16/36.

Plus 24 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to Lockwood Saddle, 5,000-7,600'.

?Brickellia microphylla (Nutt.) Gray var. *microphylla*, Small-leaved Brickellbush (see discussion below).

Scarce, central Seven Devils (Quad Lake), 7,400' ±.

Bingham and Miller 436, ID and WS, at base of cliffs in an open *Pinus albicaulis/Pinus contorta/Abies lasiocarpa* stand above the northeast side of Quad Lake, 7,400', 8/14/81 (This collection is from very high elev. for *B. microphylla*, the leaves and petioles are long, and the involucral bracts short for the species; flowers are purplish. Sent to Cronquist for verification).

Chaenactis alpina (Gray) Jones, Alpine False-yarrow.

Uncommon, higher central Seven Devils, 7,600-9,400'.

Bingham and Miller 41 and 94, ID, crevices in bedrock ridge, summit of She Devil Mt., 9,300', 7/23/79; and in crevices in bedrock bench ca. 50' south and 25' below the summit of He Devil Mt., 9,370', 7/26/79, respectively.

Christ 12465, ID, rock crevices, Seven Devils Ridge, 7/11/41.

*Christ 12676, ?NY, in sliderock on Sheep Cr. trail, 7/17/41.

Kruckeberg 3183, WS, WTU, dry, rocky, south-facing slopes at saddle at end of Seven Devils rd. (rd. 517 at Windy Saddle), 7,500', 7/30/52.

*Nelson and Nelson 3016, ?RM, top of He Devil, 8/10-15/38.

St. John and Mullen 8570, WS, rockslide off He Devil Mt., 9,000', 7/24/27.

Chaenactis douglasii Hook. and Arnott var. undet., Hoary False-yarrow.

Scarce, mostly at lower elevs., entire Seven Devils, 5,000' ±.

Burkhardt 5/30/68, IDF 68179, open slopes, Kleinschmidt Grade, 5,000', 5/30/68.

Chrysanthemum leucanthemum L., Oxeye Daisy (European escape).

Scarce (mostly at lower elevs.), central Seven Devils, 5,000-7,000'.

Bingham and Miller Sight Records: along trail 110 just east of McGaffee Cow Camp, 5,800', 8/12/81; and along the Old Boise Trail 101 between Hanson and Dog Crs., 7,000', 8/19/81.

Chrysothamnus nauseosus (Pall.) Britt. var. *artis* (A. Nels.) Cronq., the variety of Common Rabbitbrush having glabrous involucral bracts.

Scarce (mostly at lower elevs.), entire Seven Devils and lower Rapid River, 5,000' ±.

Bingham 270, ID, open grass/forb stand in the *Festuca idahoensis/Koeleria cristata* h.t., on a rocky ridgetop at Sawpit Saddle, 5,050', 8/8/81.

Bingham and Miller Sight Record, in a weedy, southeast-facing grass stand on sandy-gravelly soil ca. ¼ mi up trail 113 from its Circle C State Fish Hatchery trailhead, 2,250', 6/8/82.

Cichorium intybus L., Chicory (European introduction).

Scarce (mostly at lower elevs.), entire Seven Devils and lower Rapid River, 5,000' ±.

Bingham and Miller 561, ID and WS, in the roadway of rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Bingham and Miller Sight Record, in the trail tread at the trailhead gate of trail 113 at the Circle C State Fish Hatchery along the lower Rapid River, 2,200', 6/8/82.

Cirsium arvense (L.) Scop. var. *horridum* Wimm. and Grab., the cut-leaf variety of Canadian Thistle (European introduction).

Uncommon, central Seven Devils and lower Rapid River, 5,000-7,600'.

Bingham 542, ID and WS, in the road bed of rd. 420 ca. 0.1 mi south of Cow Cr. Saddle, 5,240', 7/21/82.

Plus 4 Sight Records by Bingham and Miller at McGaffee Cow Camp, Horse Heaven Lake, and in the Rapid River, 5,700-7,600'.

Cirsium canovirens (Rydb.) Petr., Gray-green, White-flowered Thistle.

Frequent, central Seven Devils and Rapid River, 5,000-8,000'.

Bingham and Miller 398, ID, in the bottom of Bridge Cr. ca. 1/8 mi below the Mirror Lake outlet where the manway crosses the creek, 7,900', 7/26/81.

Plus 11 Sight Records by Bingham and Miller, Dry Diggins Ridge to head of Devils Farm Cr., 6,800-7,700'.

Cirsium subniveum Rydb., Jackson's Hole Thistle.

Scarce, central Seven Devils, 7,600' ±.

Baker 12039, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Cirsium undulatum (Nutt.) Spreng., Wavy-leaved Thistle.

Occasional, northern and central Seven Devils, 5,200-6,900'.

*Christ 12631, ?NY, rock slides on trail to Baldy Lake (either trail 124 or the Baldy Lake trail), 7/15/41.

Tisdale Sight Records: plotsites 73 and 74, vicinity of Low Saddle, 5,200', 7/13/78; and plotsites 90 and 91, vicinity of Cold Springs Cow Camp, 6,600', 7/13/79.

Cirsium utahense Petr., Utah Thistle.

Scarce, central Seven Devils, 6,500-7,500'.

C. Johnson 8/14/83, BKR 2485, Plot 7035, ca. ¼ mi west of trail 110 at the Old Timer Mine and cabin, 6,550', 8/14/83.

St. John and Mullen 8536, WS, rocky ridge on Dry Diggins, 7,500', 7/22/27.

Cirsium vulgare (Savi) Tenore, Bull Thistle (European biennial weed).

Scarce (mostly at lower elevs.), entire Seven Devils, 5,000' ±.

Bingham and Miller 559, ID, in the roadbed of rd. 517 ca. ¼ mi up the road from its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Conyza canadensis (L.) Cronq. var. *glabrata* (Gray) Cronq., Horseweed.

Scarce, Rapid River only, 2,200-2,400'.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 across from Blue Gulch, 2,400', 6/8/82.

Crepis accuminata Nutt. ssp. *accuminata*, Tapertip Hawksbeard.

Occasional, northern and central Seven Devils, 5,500-7,700'.

Baker 12070, ID, rocky point above Seven Devils Guard Station, 7/21/54.

Bingham and Miller 120, ID and WS, on open, southeast-facing rocky-gravelly slope with a forb stand, on the southeast side of the Cannon-Hanson Crs. ridge ca. ½ mi north-northeast of the jct. of Hanson Cr. and the Old Boise Trail 101, 7,400', 7/15/80.

Plus 2 Sight Records by C. Johnson, Grave Point Lookout and Stevens Saddle, 5,550-7,710'.

Crepis atrabarba Heller ssp. *originalis* Babc. and Stebbins, the tall subspecies of Slender Hawksbeard.

Scarce, central Seven Devils, 7,800' ±.

Bingham and Miller 250, ID and WS, in the open sedge-grass-forb meadow of the Horse Heaven Lookout pasture just south of the Idaho-Adams Co. line ca. 0.3 mi south of the Horse Heaven Lookout cabin, 7,840', 8/27/80.

Crepis atrabarba Heller ssp. undet., Slender Hawksbeard.

Steele Sight Record, Stand 72-Pa-26, Bear-Indian Crs. divide along rd. 002, 5,100', 6/12/72.

Crepis intermedia Gray, Gray's Hawksbeard.

Scarce, southern Seven Devils and Rapid River, 5,000-7,100'.

Bingham and Miller 484 and 608, ID, south-facing, open, rocky-gravelly, grassy brushy slope in an *Agropyron spicatum/ Celtis reticulata* h.t., ca. ½ mi up the lower Rapid River trail 113 from the Circle C State Fish Hatchery trailhead gate, 2,280', 6/8/82; and open, rocky ridgetop with a sagebrush-grass stand, 200' southeast of the summit of Kinney Point, south of the spur road to the Point, 7,100', 7/27/83; respectively.

Erigeron acris L. var. *debilis* Gray, the low, glandular variety of Northern Daisy.

Occasional, central Seven Devils, 7,800-9,000'.

*Christ 12644, ?NY, small grassy meadow in talus, Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41.

Kruckeberg 3205, WS, WTU, on rocky slopes and in crevices just below Dry Diggins Lookout, 8/1/52.

St. John and Mullen 8553, WS, rockslide on He Devil Mt., 9,000', 7/24/27.

Erigeron bloomeri Gray var. *bloomeri*, Scabland Fleabane.

Scarce, central Seven Devils, 7,300' ±.

St. John and Mullen 8459, WS, gravel ridge, Dry Diggins, 7/20/27.

Erigeron compositus Pursh var. *glabratus* Macoun, Dwarf Mountain Daisy.

Common, entire Seven Devils, 5,000-9,400'.

Baker 12072, ID, rocky point above Seven Devils Guard Station, 7/21/54.

Bingham and Miller 12, 42, 43, 93, and 98, ID, and Bingham 464 and Bingham and Miller 505B, ID and WS, (12) exposed rock crevices at foot of Heavens Gate Lookout tower, 8,430', 7/21/79; (42 and 43) bedrock crevices on summit of She Devil Mt., 9,300', 7/23/79; (93 and 98) crevices in bedrock bench ca. 50' south and 25' below the summit of He Devil Mt., 9,370', 7/26/79; (464) on basalt-rock ridgetop immediately north of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82; and (505B) along trail 104 at Big Canyon Saddle, open grassland, 5,000', 6/11/82.

*Christ 8657 and 12561, ?NY, common on slopes and ridges near Black Lake, 8/8/27; and windswept ridges, Heavens Gate, 7/12/41; respectively.

Christ 12560, ID and WS, windswept ridge, Heavens Gate, 7/12/41.

Q. Jones 227, ID and WS, bare, rocky ridge, Heavens Gate, 7/13/50 (apomictic).

*Moore 97, ?WS, ridge southeast of McGaffee Cow Camp, 8,600', (actually the ridge would be nearer 6,000'), 5/16/36.

*Nelson and Nelson 3004, ?RM, top of He Devil, 8/10-15/38.

St. John and Mullen 8552, WS, rockslide on He Devil Mt., 9,000', 7/24/27 (apomictic).

Plus 10 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Erigeron disparipilis Cronq., no common name known, quite rare.

Scarce, northern Seven Devils, 5,500' ±.

C. Johnson Sight Record, Plot 793, just southwest of Grave Point Lookout, 5,550', 6/29/82.

Erigeron eatonii Gray var. *villosus* Cronq., the hairy-bracted variety of Eaton's Daisy.

Uncommon, mainly restricted to the Dry Diggins plateau between Lily Pad Lake and Hibbs Cow Camp, central Seven Devils, 6,000-8,000'.

Bingham and Miller 419, ID, on weathered Imnaha basalt along trail 112 ca. ½ mi north of Lily Pad Lake, 7,400', 8/10/81.

Christ 12719, ID, on basalt scab outcrops near the Sheep Cr. swamp, 7/17/41.

Davis 2309, WS, dry, open hillside, Dry Diggins Lookout, 6/26/40.

Henderson 3851, ID, ca. ¼ mi north-northwest of Hibbs Cow Camp near the jct. of trails 112 and 56, 7/7/77.

Kruckeberg 3207, ID, WS, WTU, dry, barren flat along plateau area of Dry Diggins, 8/1/52.

Lewis 2270, BOIS, OGDF, near Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002, at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72.

*Packard 267, ?WS, open flat on Timbered Bench, 6,000', 6/20/37.

Packard 338, WS, dry soil on open flat near Hibbs Cow Camp, 7,500', 7/28-29/37.

St. John and Mullen 8451, WS, rocky crest, Dry Diggins Area, 8,000', 7/20/27.

Plus 3 Sight Records by Bingham and Miller, Dry Diggins plateau and Horse Heaven Lookout pasture, 7,400-8,000'.

Erigeron engelmannii A. Nels., Engelmann's Daisy.

Occasional, at low elevs. in northern and southern Seven Devils, 5,000-6,700'.

Bingham and Miller 505A and Bingham 557, ID and WS, in the ridgetop grassland at Big Canyon Saddle, 5,000', 6/11/82; and on the rocky ridgetop in the grass-forb stand ca. 150' east of Grave Point Lookout, 5,630', 7/21/82; respectively.

Plus 2 Sight Records by Bingham and Miller, Cow Cr. Saddle and Horse Mt. Lookout, 5,250-6,700'.

Erigeron filifolius Nutt. var. *filifolius*, Thread-leaf Fleabane.

Scarce, northern Seven Devils, 5,000' ±.

Bingham 297, ID, on the rocky ridgetop in the grass stand at Sawpit Saddle, 5,050', 7/8/81.

?*Erigeron gracilis* Rydb., Slender Fleabane.

Steele Sight Record, Stand 81-Pa-01B, Indian Cr. 6 mi above Cuprum, sec. 31, T. 21 N., R. 2 W., 5,500', 6/24/81 (but outside the east Central Idaho, southwestern Montana, and western Wyoming distribution of this species).

Erigeron lonchophyllus Hook., Short-rayed Daisy.

Scarce, central Seven Devils, 8,700' ±.

Bingham and Miller 86, ID, in a soil pocket atop a house-size boulder in the field of giant boulders immediately north of the summit of He Devil Mt., 8,700', 7/26/79.

Erigeron peregrinus (Pursh) Greene ssp. *callianthemus* (Greene) Cronq. var. *eucallianthemus* Cronq., the wide-leaved variety of the glandular-bracted subspecies of the Subalpine Daisy.

Common, entire Seven Devils, 6,600-8,300'.

Baker 11308, ID, moist shaded slope, Sheep Rock, Hells Canyon, 9/3/53.

Bingham and Miller 16, ID, and Bingham 330, ID and WS, ca. 0.1 mi southwest of Heavens Gate Lookout, small meadow in an open subalpine fir-whitebark pine stand, 8,300', 7/21/79; and in the moderately dense Subalpine fir stand on the northwest shore of Black Lake, 7,200', 7/17/81; respectively.

Brewer 27, IDF, Six Lake Basin, 7,500', 7/20/28.

*Christ 12591 and 12714, ?NY, on cliffs in cirque below Seven Devils Lake, 7/13/41; and by marshy edge of pond, Lily Pad Lake, 7/17/41; respectively.

C. Johnson 8/12/83, BKR 2568, Plot 7025, west of trail 56 ca. ¼ mi south-southeast of Three Cr. Point, *Abies lasiocarpa/ Vaccinium scoparium* community, 7,900', 8/12/83.

Packard 439, WS, moist shaded spot in woods near the swamps, Dry Diggins, 7/28/38.

St. John and Mullen 8590, WS, wet border of Lily Pad Lake, 8,000' (actually the lake lies at 7,300'), 7/25/27.

Plus 15 Sight Records by Bingham and Miller.

Erigeron peregrinus (Pursh) Greene ssp. *callianthemus* (Greene) Cronq. var. undet.

13 C. Johnson Sight Records.

Erigeron pumilus Nutt. ssp. *intermedius* Cronq. var. *gracilior* Cronq., the low variety of the Rocky Mountain subspecies of the Shaggy Fleabane.

Uncommon (mostly at lower elevs.), entire Seven Devils and Rapid River, 5,000-7,100'.

Baker 12161, ID, grassy hillside above Slaughter Gulch, White Bird Ridge off the Little Salmon River, ? elev., 7/27/54.

Bingham 296, ID, and Bingham and Miller 529 and 609, ID and WS, rocky ridgetop, vicinity of Sawpit Saddle, 5,050', 7/8/81; weedy grassland along the lower Rapid River trail 113 ca. 0.1 mi above the Circle C State Fish Hatchery trailhead gate, 2,250', 7/1/82; and rocky ridgetop ca. 200' southeast of the summit of Kinney Point, south of the Spur road, 7,100', 7/27/83; respectively.

Plus 3 Sight Records by Bingham and Miller and C. Johnson, Sawpit Saddle, McClinery Ridge and lower Rapid River, 2,250-5,200'.

Erigeron simplex Greene, Alpine Daisy.

Scarce, central Seven Devils, 7,800' ±.

*Christ 12663, ?NY, soil pockets on talus slope, Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41.

Erigeron speciosus Lindl. var. a *macranthus* (Nutt.) Cronq., the wider- and less-hairy-leaved variety of Showy Fleabane.

Scarce, northern Seven Devils, 6,700' ±.

Davis 2276, WS and IDF, moist ravine under Douglas-fir, Grave Point Lookout, 6/24/40.

C. Johnson Sight Record, Plot 7073, in the aspen grove along the Old Boise Trail 101 ca. 1 mi south of the trail's rd. 1819 trailhead southeast of Cold Springs Lookout, 6,600', 9/1/83.

Erigeron speciosus Lindl. var. *speciosus*, the narrower- and more-hairy-leaved variety of Showy Fleabane.

Occasional, northern and central Seven Devils, 5,000-6,600'.

Baker 11990, ID, 4 mi west of Riggins, (?elev., prob. along rd. 517 in Papoose Cr.), 7/21/54.

C. Johnson Sight Records: Plot 7034, along trail 110 just west of the Old Timer Mine and spring, 6,470', 8/13/83; and Plot 7035, ca. ¼ mi west of the Old Timer Mine and spring, 6,550', 8/14/83.

Eriophyllum lanatum (Pursh) Forbes var. *lanatum*, Woolly Sunflower.

Uncommon, entire Seven Devils, 5,000-7,600'.

Baker 12287, ID, open, gravelly mountain slopes west of Seven Devils Camp, 7/31/54.

Bingham and Miller 255, ID and WS, open trail tread, along trail 124 in the head of Devils Farm Cr., 7,600', 8/28/80.

*Christ 11064 and 12704, ?NY, mountainside in Snake River Gorge near Cuprum, 5/30/40; and sliderock on west slopes along Sheep Cr. trail, 7/17/41.

St. John and Mullen 8465, WS, rocky ridge, Dry Diggins area, 7/20/27.

Plus 1 Sight Record by Tisdale, Low Saddle, 5,200'.

Gaillardia aristata Pursh, Gaillardia.

Scarce, lower Rapid River only, 2,200' ±.

Baker 12336, ID, dry, gravelly hillside along the Rapid River 3 mi west of the Little Salmon River (prob. near the present Circle C State Fish Hatchery), 8/5/54.

Bingham and Miller 527, ID and WS, weedy grassland on a rocky-sandy bench along the lower Rapid River trail 113 ca. 0.1 mi up the trail from the gate trailhead at the upper end of the Circle C State Fish Hatchery, 2,250', 7/1/82.

Haplopappus carthamoides (Hook.) Gray var. *cusickii* Gray, the narrow-bracted variety of the Large-flowered Goldenweed.

Occasional, central and southern Seven Devils, 5,000-8,000'.

Bingham and Miller 409, ID, open *Abies lasiocarpa, Picea engelmannii, Pinus albicaulis* forest, on shallow soil over bedrock, summit of trail 112 between the forks of Sheep Cr., 8,000', 8/10/81.

Cusick 2344, WS, hillsides of the Snake River near Ballard's Landing (from the date prob. along the Kleinschmidt Grade near Cuprum), 9/14/99.

St. John and Mullen 8437, WS, rocky ridge, Bernard Cr. (near McGaffee Cow Camp), 5,000', 7/19/27.

Plus 1 Sight Record by Bingham and Miller, Bernard Lakes trail 56 ca. ½ mi southwest of the lakes, 8,000', 8/11/81.

Haplopappus lanuginosus Gray var. *lanuginosus*, Woolly Goldenweed.

Frequent, central and southern Seven Devils, 6,800-8,200'.

Baker 12280, ID, open, gravelly slopes west of Seven Devils Camp, 7/31/54.

Bingham 342, and Bingham and Miller 386, ID, open *Abies lasiocarpa/Pinus albicaulis* stand near the ridgetop at the summit of trail 218 between Black Lake and Joes Gap (½ mi north-northwest of Pyramid Peak), 8,200', 7/18/81; and open *Abies lasiocarpa/Pinus albicaulis* stand on shallow-soiled ridgetop, along the Old Boise Trail 101 just west of Papoose Lake, 8,000', 7/30/81; respectively.

Christ 12485, ID and WS, open slopes and ridges, Seven Devils Ridge, 7/11/41.

Q. Jones 199, ID and WS, rocky slopes, vicinity of Heavens Gate Lookout, 7/12/50.

Ownbey and Meyer 2098, WS, gravelly soil, Heavens Gate, 6/27/40.

Packard 323, WS, rocky, dry slopes east of "The Swamps," Lily Pad Lake, 8,000', 7/28/37.

St. John and Mullen 8446 and 8607, WS, rocky crest, Dry Diggins, 7,500', 7/20/27; and rock ledge at the Sheep Cr. Narrows (prob. along trail 110 at The Narrows on the Snake-Salmon Rivers divide at the head of the north fork of Squaw Cr.), 6,800', 7/26/27; respectively.

Tisdale 7/16/79, IDF 81117, vicinity of Seven Devils Guard Station, 7,700', 7/16/79.

Plus 6 Sight Records by Bingham and Miller and Tisdale.

Helianthella uniflora (Nutt.) Torr. and Gray var. *douglasii* (Torr. and Gray) Weber, the hairy-bracted variety of the Rocky Mountain Helianthella.

Frequent, entire Seven Devils, 5,600-8,200'.

Bingham and Miller 378, ID, and Bingham 534, ID and WS, open, southeast-facing, sedge-grass slope ca. ¼ mi northeast of the Seven Devils Campground along the road to Windy Saddle, 7,600', 7/27/81; and open, southwest-facing, rocky slope ca. 0.9 mi up rd. 1819 from Buckhorn Spring and rd. 420, 6,420', 7/21/82; respectively.

Davis 2247, WS, dry hillside, Grave Point Lookout, 6/24/40.

Lewis 2264, BOIS, OGDF, Steele Stand 72-Pa-24, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,790', 6/12/72.

Packard 440, WS, exposed hillside above "The Swamps," Dry Diggins, 7,400', 7/28/38.

St. John and Mullen 8486, WS, gravel ridge, Dry Diggins, 6,500', 7/20/27.

Plus 12 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Helianthus annuus L., Common Sunflower.

Scarce, Rapid River only, 2,200' ±.

Baker 12337, ID, dry, open hillside along the Rapid River 3 mi from the Little Salmon River (prob. near the present Circle C State Fish Hatchery), 8/5/54.

Hieracium albiflorum Hook., White-flowered Hawkweed.

Common, entire Seven Devils, 5,000-7,800'.

Bingham and Miller 247, ID, half-shade of north-facing slope under lodgepole pine-Engelmann spruce-subalpine fir moderately dense stand ca. ½ mi north of the Ruth Cr. trail along trail 189, 7,000', 8/27/80.

*Christ 12684, ?NY, timbered slopes along Sheep Cr. trail, 7/17/41.

Davis 2520, WS, moist hillside, Copper Cr., Adams Co. (prob. along rd. 106 between Kinney Point and Sheep Rock), 7/2/40.

St. John and Mullen 8434, WS, woods along Bernard Cr., 5,200' (prob. along trail 110 west of McGaffee Cow Camp), 5,200', 7/19/27.

Plus 33 Sight Records by Bingham and Miller, C. Johnson, and Steele, Kirkwood Cr. to Landore, 5,200-7,800'.

?*Hieracium canadense* Michx., Canadian Hawkweed.

*Nelson and Nelson 3019, ?RM, Dry Diggins, 8/10-15/38 (but the distribution of this taxon presumably is British Columbia, Washington, and possibly Oregon).

Hieracium gracile Hook., Alpine Hawkweed.

Common, central and southern Seven Devils, 5,600-8,500'.

Baker 11303 and 12262, ID, moist shaded slopes of Sheep Rock, 9/3/53; and dry, gravelly, west-facing hillside at Heavens Gate, 7/31/54; respectively.

Bingham 90 and 133, and Bingham 347, ID, open subalpine slope with loose, gravelly-rocky, sometimes slipping soil on the northeast-facing foot of the northwest ridge off He Devil Mt., 8,450', 7/26/79; open sedge-forb-shrub meadow at the foot of a boulderfield in the bottom of Dog Cr. ca. 0.2 mi south of the creek and ½ mi below Dog Lake, 7,600', 7/16/80; and 3/4-open base of boulderfield just southwest of the east end of the largest and northeasternmost of the lakes in Six Lake Basin, 7,520', 7/18/81; respectively.

*Christ 8686 and 12605, ?NY, among grasses on high slopes near Black Lake, 8/8/37; and moist cliffs in cirque below Seven Devils Lake, 7/13/41; respectively.

Christ 12660, ID, andesitic knoll east of Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41.

C. Johnson 8/14/83 and 8/19/83, BKR 2479 and 2473; Plot 7037, west of the Old Boise Trail 101 ca. 1/3 mi southwest of Papoose Lake, *Pinus albicaulis/Luzula hitchcockii - Juncus parviflorus* community, 7,980', 8/14/83; and Plot 7041, east of trail 214 ca. ¼ mi north of Purgatory Saddle, *Abies lasiocarpa/Luzula hitchcockii* community, 7,510', 8/19/83.

Ownbey and Meyer 2074, WS, dry, rocky slope, headwaters of Sheep Cr., 6/26/40.

St. John and Mullen 8444, WS, gravelly ridgetop, Dry Diggins, 7/20/27.

Plus 13 Sight Records by Bingham and Miller, and C. Johnson.

Hieracium scouleri Hook. var. *albertinum* (Farr.) Deard. (Syn. *H. albertinum* Farr.), Western Hawkweed.

Common, entire Seven Devils, 5,200-8,200'.

Baker 12094 and 12289, ID, dry, rocky hillside below Heavens Gate, 7/21/54; and open, gravelly slopes west of Seven Devils Camp, 7/31/54; respectively.

C. Johnson 8/30/83 and 8/31/83, BKR 2583 and 2418; Plot 7060, above trail 218 just east of Joes Gap, 7,830', 8/30/83; and Plot 7066, above rd. 112 ca. 1/3 mi northeast of Rock Cr., 7,010', 8/31/83; respectively.

LaZelle 12, ID, gravelly, south-facing slope in forested area ¼ mi north of the Seven Devils Adm. Site (Guard Station), 7,500', 8/29/63.

*Nelson and Nelson 3024, RM, near rockslide, Dry Diggins trail, 8/10-15/38.

St. John and Mullen 8606, WS, rocky ledge above Sheep Cr., 7,000' (prob. near the Snake-Salmon Rivers divide along the trail 110 in the head of Old Timer Cr.), 7/26/27.

Plus 30 Sight Records by C. Johnson, Steele, and Tisdale.

Hieracium scouleri Hook. var. *cynoglossoides* (Arv.-Touv.) Deard. (Syn. *Hieracium cynoglossoides* Arv.-Touv.), Hounds Tongue Hawkweed.

Common, entire Seven Devils, 5,100-7,800'.

Bingham and Miller 202, ID and WS, and 596, ID, along the Old Boise Trail 101 ca. ¼ mi east of Horse Heaven Saddle, 7,200', 8/24/80; and along rd. 517 ca. 1 mile above its 2d crossing of Papoose Cr. in sec. 26, 5,150', 8/17/82; respectively.

*Christ 8696, ?NY, under cliffs on high, grassy slopes near Black Lake, 8/8/37.

Plus 20 Sight Records by Bingham and Miller (some of these undoubtedly being what others are calling *H. albertinum*), Cold Springs Lookout site to Black Lake, 6,400-7,900'.

?*Hieracium scouleri* Hook. var. *nudicaule* (Gray) Cronq., the subscapose variety of Woolly-weed (supposedly a California-Oregon taxon).

Baker 12298, ID, north slope of Kinney Point, 9/3/53.

Hulsea algida Gray, Alpine Hulsea.

Scarce, central Seven Devils, 7,500' ±.

Kruckeberg 3196, WS, WTU, loose scree above Sheep Lake No. 2 (Shelf Lake), 7,500', 7/31/52.

Bingham Sight Record, along the Goat Pass manway ca. ¼ mi east of Sheep Lake, 8,100', 7/25/85.

Hulsea nana Gray, Dwarf Hulsea.

Scarce, central Seven Devils, 7,800-8,500'.

*Christ 12567, on talus slopes, Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41.

St. John and Mullen 8574, WS, rockslide on exposed slopes, He Devil Mt., 8,500', 7/24/37.

Lactuca serriola L., Prickly Lettuce (European weed).

Uncommon (mostly at lower elevs.), entire Seven Devils and Rapid River, 5,000-6,600'.

Bingham and Miller 585, ID, open roadside along rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Plus 5 Sight Records by Bingham and Miller, Steele, and Tisdale, lower Rapid River and west fork Rapid River, northeast of Baldy Lake, vicinity of Low Saddle, and Bear-Indian Crs. divide, 5,200-6,600'.

Machaeranthera canescens (Pursh) Gray, Hoary Aster.

Scarce, southern Seven Devils, 5,600' ±.

Steele Sight Record, Stand 81-Pa-01B, along the Indian Cr. rd. 105 ca. 6 mi north of Cuprum, 5,550', 6/24/81.

Madia glomerata Hook., Mountain Tarweed.

Occasional, entire Seven Devils, 5,200-7,300'.

Baker 12069, ID, waste ground, rocky point above Seven Devils Guard Station, 7/21/54.

Bingham 538 and Bingham and Miller 607, ID and WS, roadside along rd. 420 ca. 0.3 mi south of Cow Cr. Saddle, 5,240', 7/21/82; and steep, southeast-facing roadcut along rd. 108 ca. ½ mi south of Lockwood Saddle, 6,600', 7/27/83; respectively.

Madia gracilis (J. E. Smith) Keck, Common Tarweed.

Uncommon, northern and north-central Seven Devils, 5,000-6,600'.

Bingham 274 and Bingham and Miller 580, ID and WS, viewpoint vicinity, Sawpit Saddle, open *Festuca idahoensis/ Koeleria cristata* h.t., 5,050', 7/8/81; and open, gravelly roadbed of rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82; respectively.

St. John and Mullen 8430, WS, gravel ridge, McGaffee Cow Camp, 5,400', 7/19/27.

Plus 2 Sight Records by C. Johnson, vicinities of McGaffee Cow Camp and Old Timer Mine, 5,900-6,550'.

Matricaria matricarioides (Less.) Porter, Pineapple Weed.

Occasional (mostly lower elevs.), central Seven Devils and Rapid River, 5,000-8,000'.

Bingham and Miller 571, ID and WS, in the roadbed of rd. 517 at the Seven Devils Guard Station pasture cattle guard at the viewpoint ca. ½ mi east of the Guard Station, 7,400', 8/17/82.

Bingham and Miller Sight Records: along the Old Boise Trail 101 ca. 1½ mi north of the Heavens Gate Lookout parking area, 8,000', 7/30/81; and at the lower Rapid River trail 113 trailhead gate at the southwest end of the Circle C State Fish Hatchery, 2,200', 6/8/82.

Microseris nutans (Geyer) Schulz-Bip., Nodding Microseris.

Common, entire Seven Devils, 5,000-8,200'.

Bingham and Miller 151 and 210, ID, and Bingham 278, 343A and 343B, ID, sedge-forb meadow in forest opening on gentle southeast-facing slope, 0.1 mi northeast of the jct. of Hanson Cr. and the Old Boise Trail 101, 6,800', 7/17/80; immediately southwest of the Horse Heaven Lookout cabin in a sedge-forb meadow on an open, rocky ridgetop, 8,200', 8/25/80; open grass-forb stand on a southwest-facing rocky hillside ca. 0.3 mi northward along rd. 2060 from Meyer Cr., 5,720', 7/8/81; and (343A and 343B) south-facing hillside with rock outcrops and an open grass-sedge stand at the summit of trail 218 between Black Lake and Joes Gap northwest of Pyramid Peak, 8,200', 7/18/81; respectively.

Brewer 98, Council R.D., head of Summit Cr., sec. 22, T. 20 N., R. 3 W., 5,000', 6/12/30.

Christ 12499, ID, grassy slopes near Seven Devils Camp, 7/12/41.

Davis 2358, IDF and WS, dry hillside, Heavens Gate, 6/28/40.

C. Johnson 7/1/83 and 8/11/83, BKR 2534 and 2592, Plot 999, 75' northwest of rd. 1819 southwest of Cold Springs Cow Camp, 6,700', 7/1/83; and Plot 7024, west of trail 112 ca. ½ mi south of Hibbs Cow Camp, *Populus tremuloides/Carex geyeri* community, 7,080', 8/11/83, respectively.

Q. Jones 196, ID and WS, soil patches on rocky hillside, Heavens Gate, 7/12/50.

Lewis 2266, BOIS, OGDF, near Steele Stand 72-Pa-24, along the Bear-Cuprum rd. 002 above Huntley Gulch, sec. 21, T. 20 N., R. 3 W., 5,790', 6/12/72.

Packard 315, WS, dry, open flat near Hibbs Cow Camp, 6/28/37.

Plus 20 Sight Records by Bingham and Miller, C. Johnson, Tisdale, and Steele.

Rudbeckia occidentalis Nutt. var. *occidentalis*, Western Cone Flower.

Frequent, entire Seven Devils, 5,000-7,300'.

Baker 11322, ID, moist ground about spring, 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham and Miller 594, ID and WS, northeast-facing, open roadbank fill along rd. 517 ca. 0.4 mi below its lower crossing of the south Fk. of Papoose Cr. along McClinery Ridge, 6,000', 8/17/82.

Brewer 79, Council R.D., Smith Mt., sec. 25 (?28), T. 21 N., R. 2 W., 7,800', 8/29/29.

Plus 16 Sight Records by Bingham and Miller and C. Johnson, Sawpit Saddle south to Rankin Mill, 5,000-7,300'.

Saussurea americana Eat., American Sawwort.

Uncommon, central and southern Seven Devils, 7,000-7,900'.

Bingham and Miller 238, ID and WS, boggy streambank area 1/3 shaded under *Abies lasiocarpa* forest, ca. 0.1 mi east of Ruth along the south side of the Ruth Lake trail, 7,200', 8/27/80.

C. Johnson 8/30/83, BKR 2465, Plot 7065, in cirque meadow ca. ¼ mi west of Black Lake along trail 214 at the south end of the 1st switchback above the lake, *Polygonum phytolaccaefolium-Lupinus caudatus* community, 7,460', 8/30/83.

Taylor 1829, WWB, rocky slope near snowfield above Sheep Lake (7,875' +), 9/17/67.

Plus 4 Sight Records by Bingham and Miller; shores of Lower Cannon Lake, 2/3 mi below Dog Lake, ½ mi up the Hanson Lakes manway, along trail 112 northwest of the Windy Saddle trailhead, 7,000-7,200'.

Senecio canus Hook., Woolly Groundsel.

Occasional, central and southern Seven Devils, 7,100-7,600'.

Baker 12055, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 610, ID and WS, open, rocky ridgetop with an open sagebrush-grass-forb stand in an *Abies lasiocarpa-Pinus albicaulis* forest ca. 250' southeast of the summit of Kinney Point, 7,100', 7/27/83.

*Christ 12512, ?NY, open, grassy mountainside 1 mi east of Seven Devils Camp, 7/12/41.

Senecio crassulus Gray, Thick-leaved Groundsel.

Abundant, entire Seven Devils, 6,200-8,200'.

Baker 12033, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 132, ID, and 214, ID and WS, northeast-facing, open, rocky slope in an *Abies lasiocarpa*, *Picea engelmannii*, *Pinus albicaulis* open stand, along the south side of the bottom of Dog Cr. ca. ¼ mi below Dog Lake, 7,600', 7/16/80; and flat, open, subalpine ridgetop in large sedge-forb meadow, immediate vicinity of Horse Heaven Lookout cabin, 8,200', 8/25/80; respectively.

*Christ 8695, ?NY, slopes above Black Lake, 8/8/37.

Christ 12565, ID and WS, timbered west slope of Heavens Gate, 7/12/41.

Cusick 2345, ?Herb., Seven Devils Mts., 8/14/99 (from the numbering of this collection, and the next (2346, *Phacelia procera* Gray) it prob. was collected along the Kleinschmidt Grade, Cuprum to Peacock Mines, with the date being Sept. 14 instead of Aug. 14. The 8/14/99 collection date came from page 286, Hitchcock and others, Part 5, 1955; it's a month too early according to Cusick's 4 other collections from what appears to be the same trip).

Davis 2323, IDF and WS, Bernard Lakes, 6/26/40.

C. Johnson 8/12/83, BKR 2566, Plot 7026, *Abies lasiocarpa/Vaccinium scoparium* community, east of the trail 56 switchbacks ca. ¼ mi south of its jct. with trail 57 ¼ mi west of Bernard Lakes, 7,740', 8/12/83.

Kruckeberg 3183, WS, WTU, dry, rocky, south-facing slopes at the end of the Seven Devils Road (rd. 517 at Windy Saddle), 7,500', 7/30/52.

LaZelle 6, ID, along rd. in Seven Devils Campground, 7,500', 8/29/63.

*Nelson and Nelson 2984, ?RM, Horse Heaven, 8/10-15/38.

Packard 441, WS, trail to "The Swamps" from Hibbs Cow Camp, 7,600', 7/28/38.

St. John and Mullen 8456, WS, Dry Diggins Area, 7,300', 7/20/27.

Plus 33 Sight Records by Bingham and Miller and C. Johnson.

Senecio cymbalarioides Buek, Alpine Meadow Butterweed.

Scarce, central Seven Devils, 7,300' ±.

*Christ 12730, ?NY, in marsh, Sheep Cr. Swamp, 7/17/41.

Senecio foetidus Howell var. *hydrophiloides* (Rydb.) T. M. Barkley, the radiate-headed, open-inflorescenced variety of Sweet Marsh Butterweed.

Occasional, northern Seven Devils and Rapid River, 5,000' ±.

Bingham and Miller 492, ID and WS, northwest-facing, half-shaded, moderately moist open *Pseudotsuga menziesii, Pinus ponderosa, Betula, Acer* forest, Douglas-fir/Ninebark h.t., ca. 3/4 mi up the lower Rapid River trail 113 from Blue Gulch, 2,560', 6/8/82.

Plus 2 Bingham and Miller Sight Records: along the west Fk. Rapid River trail 113 ca. 0.1 mi east of Bridge Cr., 3,700', 6/8/82; and along the stock-drive part of trail 104 ca. ¼ mi east of Big Canyon Saddle, 4,900', 6/11/82.

Senecio fremontii Torr. and Gray var. *fremontii*, Dwarf Mountain Butterweed.

Uncommon, central and southern Seven Devils, 8,400-9,000'.

Bingham and Miller 9 and 88, ID, and 362, ID and WS, open bedrock bench immediately west of Heavens Gate Lookout tower, 8,430', 7/21/79; foot of northeast-facing, loose gravelly rocky ridge, the northwest ridge off He Devil Mt., ca. ½ mi northwest of the summit, 8,450', 7/26/79; and east-facing, 1/3-shaded, moderately dry soil pockets trapped in bedrock, east shore above Mirror Lake, 8,050', 7/26/81; respectively.

*Christ 8667 and 12541, ?NY, grassland in glacial cirque, Pyramid Peak, 8/8/37; and ledges on peak, Heavens Gate, 7/12/41; respectively

St. John and Mullen 8568, WS, among loose rockslides in the alpine region of He Devil Mt., 9,000', 7/24/27.

Senecio integerrimus Nutt. var. *exaltatus* (Nutt.) Cronq., the broad-bracted and yellow-rayed variety of Western Groundsel.

Frequent, northern and central Seven Devils, 5,100-8,100'.

Bingham 458, ID and WS, west-facing, open, rocky slope in an open grass-forb-rigid sage stand, immediately south of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.

*Christ 12517 and 12717, ?NY, open, grassy mountainside 1 mi east of Seven Devils Camp, 7/12/41; and in marsh, Sheep Cr. Swamp, 7/17/41; respectively.

Q. Jones 223, WS, rocky slopes in eroded areas, Heavens Gate, 7/13/50.

Packard 287, WS, rather moist slope above the head of the north Fk. of Little Granite Cr., 7,400', 6/26/37.

Plus 11 Sight Records by Bingham and Miller and C. Johnson, Camp Howard Triangulation Station south to Stevens Saddle, 5,100-8,100'.

Senecio pseudaureus Rydb. var. *pseudaureus*, Streambank Butterweed.

Scarce, central Seven Devils, 5,400-7,300'.

*Nelson and Nelson 2976, ?RM, Dry Diggins Camp, 8/10-15/38.

St. John and Mullen 8354, WS, thicket, McGaffee Cow Camp, 5,400', 7/17/27.

Senecio streptanthifolius Greene, Rocky Mountain Butterweed.

Common, entire Seven Devils, 6,600-7,900'.

Baker 12066, ID, dry, rocky banks above Seven Devils Guard Station, 7/21/54.

Bingham and Miller 139, ID, east-facing, open, rocky slope along the edge of a boulderfield in an open *Abies lasiocarpa, Picea engelmannii, Pinus albicaulis* stand, along the south side of the bottom of Dog Cr. ca. 3/5 mi below Dog Lake, 7,500', 7/16/80.

*Christ 12511 and 12634, ?NY, open, grassy mountainside 1 mi eas of Seven Devils Camp, 7/12/41; and timbered hillside, trail to Baldy Lake, 7/15/41; respectively.

Christ 12520, ID and WS, open, grassy east slopes, Heavens Gate, 7/12/41.

C. Johnson 8/9/83 and 8/11/38, BKR 2498 and 2495, *Pseudotsuga menziesii-Abies lasiocarpa/Calamagrostis rubescens-Lupinus caudatus* community, Plot 7005, west of the Old Bois Trail 101 ca. 0.1 mi south of Dog Cr., 6,950', 8/9/83; and Plot 7024, *Populus tremuloides/Carex geyeri* community, west of trail 112 ca. ½ mi south of Hibbs Cow Camp, 7,060', 8/11/83; respectively.

Kruckeberg 3208, WS, and WTU, on steep talus and grass slopes just east of the Dry Diggins plateau 6 mi west of Windy Saddle, 8/1/52.

St. John and Mullen 8485, WS, rocky ridge, Dry Diggins, 7,000', 7/20/27.

Tisdale 7/16/79, IDF 80177, subalpine grassland, Seven Devils Guard Station pasture, 7,500', 7/16/79.

Plus 24 Sight Records by Bingham and Miller and C. Johnson.

Senecio triangularis Hook. var. *triangularis*, Arrow-leaved Groundsel.

Abundant, entire Seven Devils, 5,700-8,000'.

Baird 8/20/71, Council R.D., Bear Cr., 5,000', 8/20/71.

Baker 11321 and 12254, ID, moist ground about spring in open woods 6 mi north of Cuprum (prob. along rd. 106), 9/3/53; and moist woods along Shingle Cr. (prob. along rd. 517), 7/31/54; respectively.

Bingham and Miller 225, ID and WS, west-facing, open talus slop beneath rimrock along the west side of the Horse Heaven Lookout pasture ca. ¼ mi southwest of the Lookout cabin, 8,000', 8/25/80.

*Christ 12424, ?NY, in marsh, Sheep Cr. Swamp, 7/17/41.

LaZelle 7, ID, shores of Seven Devils Lake, 8/29/63.

Packard 442, WS, mountain meadow near Lily Pad Lake, 7,500', 7/28/38.

St. John and Mullen 8537, WS, open ridge, McGaffee Cow Camp, 5,400', 7/23/27 (date is out of the numbering sequence and habitat seems to be unusual; a holdover, or locality mix up?).

Plus 33 Sight Records by Bingham and Miller and C. Johnson.

Solidago canadensis L. var. *salebrosa* (Piper) Jones, the imbricate-involucred and less hairy variety of Canadian Goldenrod.

Uncommon, central and southern Seven Devils, 5,100-8,500'.

Baker 11314, ID, grassy, open meadow, Kinney Point, 9/3/53.

Bingham and Miller 257, ID and WS, southwest-facing, open fores glade with a sedge-forb stand and patches of *Populus tremuloides*, along trail 124 ca. ¼ mi south of Fall Cr. an just west of Potato Hill, 7,500', 8/28/80.

Brewer 114, Council R.D., Jackley Guard Camp (or Station, apparently north of but near the Lookout), sec. 12, T. 21 (?22) N., R. 3 (?2) W., 7,000', 8/17/30.

McDowell 2, Council R.D., Placer Cr. (Fk. of Indian Cr.), 5,500', Sept., 1926.

Plus 4 Sight Records by Bingham and Miller, just northwest of Echo Lake; in Horse Heaven Cr. 0.1 mi north of the Old Boi Trail 101; along rd. 517 1 mi above its 2d crossing of Papoose Cr. in sec. 26; and along the Old Boise Trail 101 ca. 1/3 mi southwest of Dog Cr., 5,150-7,200'.

Solidago missouriensis Nutt. var. *missouriensis*, Missouri Goldenrod.

Uncommon, northern and central Seven Devils, 5,200-6,900'.

C. Johnson 8/13/83 and 8/13/83, BKR 2474 and 2486, Plot 7034, along trail 110 just west of the Ralph Barton cabin at Old Timer Spring and Mine, 6,470', 8/13/83; and at the Old Timer Spring, 6,930', 8/13/83; respectively.

C. Johnson Sight Records: Plot 719, 2/3 mi northwest of Motthor Saddle, 5,180', 5/25/82; Plot 786, ½ mi down Caribou Cr. from rd. 2060, 5,260', 6/27/82; and Plot 7035, ca. ¼ mi west of the Old Timer mine and cabin, 6,550', 8/14/83.

St. John and Mullen 8432, WS, rocky crest, Bernard Cr., 5,600', 7/19/27.

Taraxacum officinale Weber, Common Dandelion (European introduction).
Common, entire Seven Devils and Rapid River, 5,000-8,300'.
Bingham 560, ID and WS, ridgetop roadbed ca. 100' north of the Grave Point Lookout tower, 5,630', 7/21/82.
Plus 33 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to Lockwood Saddle, 5,000-8,300'.

Tragopogon dubius Scop., Yellow Salsify (European introduction).
Frequent, entire Seven Devils and Rapid River, 5,000-7,600'.
Bingham and Miller Sight Records: vicinities of Cow Cr. Saddle, 5,050'; Big Canyon Saddle, 5,050'; Dry Diggins Ridge trail just north of the drop-off 2¼ mi north of the Iron Phone, 7,300'; just west of the Old Boise Trail in Hanson Cr., 6,800'; Horse Heaven Lake, 7,600'; Circle C State Fish Hatchery, 2,200'; along rd. 517 2/3 mi above its 2d crossing of Papoose Cr. in sec. 26, 5,000'; along the Old Boise Trail ca. ½ mi southwest of Horse Heaven Cr., 7,100'; Grave Point Lookout, 5,630'; along trail 112 just northwest of Windy Saddle, 7,500'; along trail 124 ca. ¼ mi northwest of the south fork of Little Granite Cr., 6,650'; and along trail 113 in the west fork of the Rapid River just west of the main forks in sec. 26, 2,700'.
C. Johnson Sight Records: Plot 786, below rd. 2060 just north of Caribou Cr., 5,260'; and Plot 793, just southwest of Grave Point Lookout, 5,550'.
Steele Sight Record, Stand 72-Pa-25, at the Bear-Indian Crs. divide along rd. 002, 5,130'.

Tragopogon pratensis L., Meadow Salsify (European introduction).
Scarce, central Seven Devils, 5,000' ±.
*Packard 264, ?WS, open flat on Timbered Bench, ? elev., 6/20/37.

Wyethia helianthoides Nutt., White-rayed Wyethia.
Scarce, southern Seven Devils, 5,800' ±.
Bingham and Miller 517, ID, south-facing, 1/5-shaded, gentle slope with a grass-forb-sedge meadow in an opening in a *Pinus ponderosa, Pseudotsuga menziesii, Abies grandis, Larix occidentalis* stand along rd. 112 ca. 1½ mi south of Placer Basin, 5,850', 6/30/82.

rberidaceae

Berberis repens Lindl., Creeping Oregon Grape.
Frequent, central and southern Seven Devils and Rapid River, 5,000-7,300'.
Bingham and Miller 182, ID, open Douglas-fir stand on east-facing slope along the Old Boise Trail ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.
Plus 19 Sight Records by Bingham and Miller and C. Johnson, Cold Springs Lookout site to Lockwood Saddle, 5,800-7,200'.

Btulaceae

Alnus sinuata (Regel) Rydb., Wavy-leaved Alder.
Common, entire Seven Devils and west Fk. Rapid River, 5,000-7,200'.
Baker 11318, ID, moist ground about spring, 6 mi north of Cuprum (prob. on rd. 106), 9/3/53.
Bingham and Miller 370, ID, north shore of Lower Cannon Lake, 7,000', 7/27/81.
Brewer 77, Council R.D., Lost Basin, sec. 26 (?22), T. 21 N., R. 2 W. (directly northeast of Smith Mt.), 7,800', 8/16/29.
*Christ 12691, ?NY, springy mountainside along the Sheep Cr. trail, 7/17/41.
Moore 86, WS, Bernard Cr. trail (no. 110), McGaffee Cow Camp, 8,600' (actually the Camp is at 5,700'), 5/16/36.
Plus 19 Sight Records by Bingham and Miller and C. Johnson, Meyer Cr. to old Landore.

Betula occidentalis Hook. var. *occidentalis*, Water Birch.

Scarce, Rapid River only, 2,200-2,800'.

Bingham and Miller Sight Records, bottom of the lower Rapid River just above the Circle C State Fish Hatchery, 2,250', 6/8/82; and just west of the main forks of the Rap River along trail 113, 2,800', 6/9/82.

Boraginaceae

Amsinckia retrorsa Suksd., Tarweed or Rigid Fiddleneck.

Occasional, lower northern Seven Devils and Rapid River, 5,000' ±.

Bingham 295, ID, in *Agropyron spicatum/Festuca idahoensis* stand at Sawpit Saddle, 5,050', 7/8/81.

Plus 2 Rapid River Sight Records by Bingham and Miller.

Asperugo procumbens L., Madwort (Eurasian introduction).

Scarce, lower Rapid River, 2,200' ±.

Bingham and Miller 500, moist, partly shaded trailside at the Circle C State Fish Hatchery trail 113 trailhead gate, 2,200', 6/10/82.

Cryptantha affinis (Gray) Greene, White Forget-me-not.

Uncommon, entire Seven Devils, 5,000-7,800'.

Baker 12067, ID, dry, rocky banks above Seven Devils Guard Station, 7/21/54.

Davis 2356, WS, Heavens Gate, 6/25-28/40.

Plus 6 Sight Records by Bingham and Miller and Steele, Cold Springs Lookout to Bear-Indian Cr. divide along rd. 002, 5,100-7,800'.

Cryptantha torreyana (Gray) Greene, Torrey's White Forget-me-not.

Occasional (mostly at lower elevs.), northern and central Seven Devi and Rapid River, 5,000-5,200'.

Bingham and Miller 488 and 588, ID and WS, south-facing, open, rocky slope in an *Agropyron spicatum/Celtis reticulata* h.t ca. 1¼ mi up the lower Rapid River trail from the trailhead gate at the Circle C State Fish Hatchery, 2,400', 6/8/82; and east-facing, open, clearcut *Pseudotsug menziesii, Pinus ponderosa, Abies grandis* forest along rd. 517 on lower McClinery Ridge ca. ½ mi above the roads 2d crossing of Papoose Cr. in sec. 26, 4,900', 8/17/82; respectively.

Tisdale Sight Record, Plots 73 and 74, vicinity of Low Saddle, 5,200', 7/13/78.

Cynoglossum officinale L., Common Hounds-tongue (European introduction).

Uncommon, entire Seven Devils and Rapid River, 5,000-7,800'.

Bingham and Miller 556, ID and WS, open, rocky, ridgetop roadside ca. 100' north of the Grave Point Lookout tower, 5,360', 7/21/82.

Plus 5 Sight Records by Bingham and Miller: Big Canyon Saddle to Black Lake, 5,000-7,800'.

Hackelia cinerea (Piper) Johnst., Gray Stickseed.

Scarce, Rapid River only, 2,300' ±.

Bingham and Miller 481, ID and WS, open, south-facing, rocky slope in an *Agropyron spicatum/Celtis reticulata* h.t. ca. ½ mi up the lower Rapid River trail 113 from the trailhead gate at the upper end of the Circle C State Fish Hatchery, 2,280', 6/8/82.

Hackelia floribunda (Lehm.) Johnst., Many-flowered Stickseed.

Occasional, central and southern Seven Devils, 7,600' ±.

Baird 6/12/72, Council R.D., along Indian Cr. 2 mi above Cuprum, 5,000', 6/12/72.

Baker 12011, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Christ 12506, ID and WS, edge of conifers, Seven Devils camp, 7/12/41.

Hackelia hispida (Gray) Johnst., Rough Stickseed, quite rare.

Occasional, central Seven Devils, 7,200-7,500'.

Bingham and Miller 416, ID and WS, in small, loose, talus rock on a south-facing slope ca. ¼ mi east of the jct. of trails 112 and 140, 7,200', 8/10/81; and Sight Record, along Dry

Diggins Ridge trail 140 ca. 3/4 mi north of its jct. with trail 112 at the Iron Phone, 7,300', 8/12/81.

Christ 12674, ID, NY, slide rock along the Sheep Cr. trail, 7/17/41.

Davis 2331, IDS, NY, WS, sliderock and dry hillside along Sheep Cr. trail, 6/26/40.

Kruckeberg 3200, ID, IDS, NY, OSC, WS, WTU, on steep, sterile, metamorphic talus of west-facing slopes bordering main Sheep Cr. drainage 4½ mi from the Seven Devils rd. (rd. 517 at Windy Saddle), 7,500', 8/1/52.

Hackelia micrantha (Eastw.) J. L. Gentry, Tall Blue Forget-me-not.

Common, entire Seven Devils, 5,300-8,400'.

Bingham and Miller 24, ID, and 107 and 504, ID and WS, open and exposed east-facing slope in loose rock of bedrock ridge ca. 0.2 mi south-southwest of Heavens Gate Lookout, 8,350', 7/21/79; open, south-facing bottom of Bridge Cr. ca. 0.1 mi north of Seven Devils Guard Station, 7,250', 7/14/80; and grassy, open forest slope near ridgetop (Snake-Salmon Rivers divide) along rd. 672 ca. ½ mi south of Mud Springs Ridge, 5,300', 6/10/82; respectively.

Davis 2388, IDF and WS, dry hillside, Heavens Gate, 6/28/40.

Gentry and Davidse 1726, ID, 15 mi west of Riggins along a rd. (517) starting 0.5 mi south of Riggins, 7,100', 7/19/67.

Q. Jones 203, ID and WS, edge of timber on grassy slopes, vicinity of Heavens Gate Lookout, 7/12/50.

Packard 311 and 457, WS, dry, open flat near Hibbs Cow Camp, 8,000', 6/28/37; and moist rockslide on Brundage Trail between the forks of Sheep Cr. ½ mi way up from the west fork, 7,000', 7/28/38; respectively.

St. John and Mullen 8473, WS, grass ridge, Dry Diggins, 6,500', 7/20/27.

Plus 23 Sight Records by Bingham and Miller, and C. Johnson.

Lithospermum arvense L., Corn Gromwell (introduced Eurasian weed).

Scarce, southern Seven Devils, 5,000' ±.

Christ 11071, ID and WS, mountainside in Snake River Gorge near Cuprum, 5/30/40.

Lithospermum ruderale Dougl., Western Stoneweed.

Frequent, northern and central Seven Devils and Rapid River, 5,000-6,600'.

13 Sight Records by Bingham and Miller, C. Johnson, and Tisdale: Big Canyon Saddle to vicinity McGaffee Cow Camp and lower and west fork Rapid River, 5,000-6,600'.

Mertensia longiflora Greene, Long-flowered Bluebells.

Occasional, northern and north-central Seven Devils, 5,200-5,900'.

Bingham 465, ID, open grass-forb-rigid sage stand on basalt rock ridgetop immediately north of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.

Meyer 856, WS, talus slopes above Bernard Cr. 3 mi from Snake River, ? elev., 5/13/37.

Packard 587, WS, moist north slope under open pine stand, near Stormy Point, Low Saddle, 5/13/39.

Mertensia oblongifolia (Nutt.) G. Don, Leafy Bluebells.

Occasional, northern and north-central Seven Devils, 5,200-5,700'.

Bingham and Miller Sight Records: along trail 104 ca. 1 mi south of Camp Howard Triangulation Station, 5,400', 6/11/82; and along rd. 672 just north of Cow Cr. Saddle, 5,250', 6/10/82.

C. Johnson Sight Record, Plot 719, below trail 104 ca. 2/3 mi northwest of Motthorn Saddle, 5,180', 5/25/82.

Moore 88, WS, ca. ¼ mi down the Bernard Cr. trail 110 from McGaffee Cow Camp, 7,500' (actually nearer 5,600' since the Camp is at 5,700'), 5/16/36.

Mertensia paniculata (Ait.) G. Don var. *borealis* (Macbr.) Williams, the glabrous-leaved variety of Tall Bluebells.

Common, entire Seven Devils and west fork Rapid River, 5,000-8,400'.

Baird 6/12/72, Council R.D., along Indian Cr., 2 mi above Cuprum, 5,000', 6/12/72.

Baker 12062, ID, wet ground around spring, Seven Devils Guard Station, 7/21/54.

Bingham and Miller 11, ID, and 222, ID and WS, along the rocky crest of the Snake-Salmon Rivers divide ca. 0.2 mi southwe of Heavens Gate Lookout, 8,350', 7/21/79; and beside snowbanks in the moist talus slopes below the rimrock at the upper west edge of the Horse Heaven Lookout pasture ca ¼ mi southwest of the Lookout cabin, 8,000', 8/25/80; respectively.

*Christ 8627, ?NY, springy places on mountainside, Black Lake, 8/8/37.

Christ 12480 and 12539, ID, in *Pinus albicaulis* groves, Seven Devils Ridge, 7/11/41; and fissures in cliffs on peak, Heavens Gate, 7/12/41; respectively.

Davis 6/28/40, IDF 83037, creek bank, Heavens Gate, 6/28/40.

*Packard 295, ?WS, bank of the north fork of Little Granite Cr. 7,600', 6/26/37.

*St. John and Mullen 8455, ?WS, grassy meadow by creek, Dry Diggins, 7,300', 7/20/27.

Plus 31 Sight Records by Bingham and Miller, and C. Johnson, including west fork Rapid River.

Myosotis discolor Pers., Yellow and Blue Forget-me-not.

Occasional (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000-5,400'.

Bingham 300, ID, weedy-grassy, sheep-driveway under open *Pinus ponderosa, Pseudotsuga menziesii* stand at Low Saddle, 5,400', 7/8/81.

Bingham and Miller Sight Records: in the *Agropyron spicatum-Festuca idahoensis* grassland just north of Big Canyon Sadd along trail 104, 5,000', 6/11/82; and along the west fork Rapid River trail 113 in the McCrea Place pasture, 4,000', 6/9/82.

Tisdale Sight Record, vicinity of Low Saddle, 5,200', 7/13/78.

Plagiobothrys scouleri (Hook. and Arnott) Johnst. var. *penicillatus* (Greene) Cronq., the interior variety of the Douglas Popcorn-flower.

Scarce, southern Seven Devils, 5,300' ±.

Bingham and Miller 521, ID and WS, south-facing, open, rocky ro bed in a sedge-forb meadow, in the road on the east side of Indian Cr. north leading from the bridge where rd. 105 crosses Indian Cr. at old Landore, 5,330', 6/30/82.

Brassicaceae

Alyssum alyssoides L., Pale Alyssum (European introduction).

Uncommon, lower northern Seven Devils, 5,000-6,000' and Rapid River.

*Baker 11993, ?ID, open woods 4 mi west of Riggins (along rd. 517 prob. in Papoose Cr.), ? elev., 7/21/54.

Bingham 276, ID, and Bingham and Miller 522, ID and WS, open *Agropyron spicatum/Festuca idahoensis* site at Sawpit Saddle, 5,050', 7/8/81; and along trail 113 ca. 0.1 mi up the trail from the Circle C State Fish Hatchery trailhead gate, 2,250', 7/1/82; respectively.

Davis 2275, WS, moist ravine, Grave Point Lookout, 6/24/40.

Plus 2 Sight Records by C. Johnson.

Alyssum desertorium Stapf, Desert Alyssum (Old World introduction).

Scarce, lower northern Seven Devils, 5,000' ±, and Rapid River.

Bingham and Miller 483, ID and WS, open, south-facing *Agropyron spicatum* slope ca. ½ mi up trail 113 in the lower Rapid River from the Circle C State Fish Hatchery trailhead gate, 2,280', 6/8/82.

Bingham and Miller Sight Record, along trail 104 just north of Big Canyon Saddle, 5,050', 6/11/82.

Arabis crucisetosa Const. and Rollins, Cross-haired Rockcress.

Occasional, northern and central Seven Devils, 5,000-8,500'.

Meyer 845 and 1612, WS, shaded hills 3 mi up and above Sheep Cr., ? elev., 5/13/37; and moist protected places in shade of *Pseudotsuga* and *Pinus ponderosa* above Sheep Cr., ? elev., 5/12/39; respectively.

*Moore 79, ?WS, Bernard Cr. trail (110), 3 mi from Snake River, 6,000', 5/16/36.

Packard 350, WS, McGaffee Cow Camp in the head of the north fork of Bernard Cr., 5,500', 6/29/37.

St. John and Mullen 8558, WS, rockslide on He Devil Mt., 9,000', 7/24/27.

Arabis divaricarpa Nels., Spreading-pod Rockcress.

Uncommon, central and southern Seven Devils, 7,400-8,400'.

*Baker 12269, ?ID, dry, gravelly hillside on west side of Heavens Gate, 7/31/54.

*Christ 12477, ?NY, slopes near crest of Seven Devils Ridge, 7/11/41.

C. Johnson 8/10/83, BKR 2468, Plot 7015, east of trail 124 ca. 0.1 mi west of the summit of Potato Hill, *Artemisia tridentata/Festuca idahoensis* community, 7,730', 8/10/83.

Q. Jones 211, WS, scattered on rocky slopes, Heavens Gate, 7/12/50.

Plus 3 Sight Records by C. Johnson, including Six Lake Basin area.

Arabis drummondii Gray, Drummond's Rockcress.

Scarce, central Seven Devils, 7,600-8,000'.

Christ 12510, ID and WS, open hillside 1 mi east of Seven Devils Camp, 7/12/41.

Arabis hirsuta (L.) Scop. var. *glabrata* Torr. and Gray, the Hairy Rockcress variety having narrow seed pods.

Common, entire Seven Devils, 6,300-7,600'.

Bingham and Miller 113 and 138, ID and WS, moderately dry rocky slope in the vicinity of Windy Saddle, 7,600', 7/14/80; and in an *Abies lasiocarpa-Picea engelmannii* forest in the bottom of Dog Cr. ca. 3/5 mi below the lake, 7,500', 7/16/80; respectively.

Christ 12592, ID, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Plus 23 Sight Records by Bingham and Miller and C. Johnson.

Arabis holboellii Hornem. var. *pendulocarpa* (Nels.) Rollins, the nonauricular-leaved variety of Holboell's Rockcress.

Scarce, central Seven Devils, 6,550-7,250'.

C. Johnson 8/9/83, BKR 2489, Plot 7007, northeast shore of Haas Lake *Carex hoodii-Potentilla glandulosa* moraine community, 7,240', 8/9/83; and Sight Record Plot 7035, ca. ¼ mi west of trail 110 at the Old Timer Mine and spring, 6,550', 8/14/83.

Arabis holboellii Hornem. var. *retrofracta* (Grah.) Rydb., the auricular-leaved, narrow seed-podded variety of Holboell's Rockcress.

Common, entire Seven Devils, 5,000-7,600'.

*Baker 12288, ?ID, open, gravelly mountain slopes west of Seven Devils Camp, 7/31/54.

Bingham and Miller 513, ID and WS, ca. 0.1 mi up rd. 106 from Lockwood Saddle, in *Pseudotsuga menziesii-Pinus ponderosa* open forest on rd. cut, 6,400', 6/30/82.

*Christ 12489, ?NY, windswept points, Seven Devils Ridge, 7/11/41.

Christ 12508, ID, open mountainside 1 mi east of Seven Devils Camp, 7/12/41.

C. Johnson 8/31/83 BKR 2449, Plot 7067, below trail 217 in the head of Deep Cr. ca. 0.1 mi northwest of rd. 112, disturbed *Agastache urticifolia-Polygonum phytolaccaefolium-Lupinus sericeus* community, 7,150', 8/31/83.

Plus 15 Sight Records by Bingham and Miller and Tisdale.

Arabis lemmonii Wats. var. undet., Lemmon's Rockcress.

St. John and Mullen 8545, WS, rocky summit of He Devil Mt., 9,200', 7/24/27.

Arabis lignifera A. Nels., Woody-branched Rockcress.

Scarce, central and southern Seven Devils, 6,400-7,800'.

Bingham and Miller 514, ID and WS, open grass-sedge-forb stand on rocky ridgetop, Lockwood Saddle, 6,400', 6/30/82.

*Nelson and Nelson 3018, ?RM, Dry Diggins Lookout, 8/10-15/38.

Arabis lyallii Wats., Lyall's Rockcress.

Uncommon, central Seven Devils, 7,400-8,400'.

Baker 12046, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

*Christ 12456, 12537, and 12615, ?NY, in tundra and on grassy slopes above Seven Devils Lake, 7/11/41; in tundra on peak, Heavens Gate, 8,500', 7/12/41; and rocky point on promontory jutting into Sheep Lake No. 2 (Shelf Lake), 7/14/41; respectively.

Christ 12488, ID, wind-swept ridge, Seven Devils Ridge, 7/11/41.

Packard 305, WS, dry, rocky outcropping near ridge off He Devil Mt. above Sheep Lake, 9,000' (from correspondence it's known that Packard was with the Hibbs family traveling roughly along the route of present trail 123, thus the elev. of the ridge above Sheep Lake is nearer 8,400'), 6/27/37.

Arabis microphylla Nutt. var. *microphylla*, Littleleaf Rockcress.

Scarce, northern and central Seven Devils, 5,000-8,000'.

Bingham and Miller 359, ID, crevices in bedrock in open *Abies lasiocarpa/Pinus albicaulis* forest, above the east shore of Mirror Lake, 7/26/81.

Packard 563, WS, rocky north slope of ridge above Sheep Cr. 4 mi from mouth, ? elev., 5/12/39.

Arabis microphylla Nutt. var. *saximontana* Rollins, the upright and many-siliqued variety of Littleleaf Rockcress.

Scarce, central Seven Devils, 7,800' ±.

C. Johnson 8/20/83, BKR 2466, Plot 7046, near the jct. of trails 192 and 113 ca. ¼ mi north of Carbonate Hill, *Pinus albicaulis/Polemonium pulcherrimum* community, 7,770', 8/20/83.

Arabis platysperma Gray var. *howellii* (Wats.) Jeps., Broad-seeded Rockcress.

Scarce, northern Seven Devils, 6,600' ±.

Bingham 311, ID, on open, weathered, reddish basalt ca. 0.2 mi east-northeast across rd. 1819 from Cold Springs Cow Camp, 6,620', 7/10/81.

Arabis sparsiflora Nutt. var. *sparsiflora*, Sicklepod Rockcress.

Scarce, central Seven Devils, 8,200-8,400'.

Christ 12534, ID, open east slopes, Heavens Gate, 7/12/41.

Arabis sparsiflora Nutt. var. undet.

*Christ 11078, ?NY, on roadbank, Cuprum, 5/30/40.

Arabis suffrutescens Wats., Woody Rockcress.

Scarce, western central Seven Devils, 7,300-7,600'.

*Christ 12721, ?NY, basaltic knob near Sheep Cr. Swamp, 7/17/41.

Ownbey and Meyer 2083, WS, gravelly, exposed ridge, Hibbs Cow Camp, 6/26/40.

Chorispora tenella (Pall.) DC., Blue Mustard (European introduction).

Scarce, lower Rapid River only, 2,200' ±.

Bingham and Miller 482, ID and WS, grassy-brushy south-facing rocky slope along the lower Rapid River trail 113 ca. ½ mi above the Circle C State Fish Hatchery trailhead gate, 2,280', 6/8/82.

Descurainia richardsonii (Sweet) Schulz var. *viscosa* (Rydb.) Peck, the glandular variety of Mountain Tansy-mustard.

Common, entire Seven Devils, 5,200-8,000'.

Baker 12034 and 12077, ID, open alpine slopes, Seven Devils Cam 7/21/41; and moist soil about spring, Seven Devils Guard Station, 7/21/41; respectively.

Bingham and Miller 141A, and Bingham 312 and 313, ID, east-facing, open, sedge and forb-covered slope in the bottom of Dog Cr. ca. 3/5 mi below Dog Lake, 7,500', 7/16/80; and (both 312 and 313) south-facing, rocky hillside with an op sedge-forb stand ca. 1½ mi east of Cold Springs Lookout along rd. 1819 near Buckhorn Spring, 6,440', 7/8/81; respectively.

Brewer 26, Council R.D., Six Lake Basin, sec. 5, T. 21 N., R. 3 (?2) W., 7,500', 7/20/28.

Plus 18 Sight Records by Bingham and Miller, Caribou Cr. to Lockwood Saddle, 5,600-8,000'.

Draba oligosperma Hook. var. *oligosperma*, Few-seeded Draba.

Scarce, central Seven Devils, 8,400' ±.

Christ 12468, ID and WS, and 12556, ID, rock crevices on Seven Devils Ridge, 7/11/41; and rocky shingle of ridge, Heavens Gate, 7/12/41; respectively.

Draba verna L. var. *boerhaavii* VanHall, Spring Whitlow Grass.

Occasional, northern Seven Devils, 5,000-5,700'.

Bingham 463, ID, basalt-rock, open ridgetop immediately north of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.

Bingham and Miller Sight Records: along trail 104 ca. ¼ mi south of Camp Howard Triangulation Station, 5,700', 6/11/82; and along rd. 672 just north of Cow Cr. Saddle, 5,250', 6/10/82.

Erucastrum gallicum (Willd.) Schulz, Dog Mustard (European weed).

Scarce, central Seven Devils, 7,500' ±.

Bingham and Miller 141B, opening on an east-facing rocky slope in a *Abies lasiocarpa/Picea engelmannii/Pinus albicaulis* stand in the bottom of Dog Cr. ca. 3/5 mi below Dog Lake, 7,500', 7/16/80.

Erysimum asperum (Nutt.) DC., Rough Wallflower.

Occasional, northern and central Seven Devils and Rapid River, 5,000-6,500'.

St. John and Mullen 8464, WS, rocky ridge, Dry Diggins, 6,500', 7/20/27.

Plus 2 Rapid River Sight Records by Bingham and Miller and another from Low Saddle by Tisdale, 2,300-5,200'.

***Halimolobos perplexa* (Hend.) Rollins var. *perplexa*, Puzzling Halimolobos.

Rare, entire Seven Devils, 6,600-8,000' ± (recommended for Federal Threatened Status pending more information, Steele and others 1981.)

Bingham 310, ID, on open, reddish, weathered basalt just east-northeast across rd. 1819 from Cold Springs Cow Camp, 6,620', 7/10/81.

*Christ 8614, ?NY, gravel slide, Smith Mt., 8/8/37.

Christ 12708, ID and NY, sliderock on west slopes along the Sheep Cr. trail, 7/17/41.

Phoenicaulis cheiranthoides Nutt., Dagger-pod.

Scarce, central Seven Devils (on basalt), around 7,600'.

Bingham and Miller 428, ID, on decomposed basalt with a sparse grass-forb stand in a large opening of an *Abies grandis, Pinus albicaulis, Pinus contorta* stand, in the "Y" at the jct. of trails 112 and 56 ca. ½ mi north-northeast of Hibbs Cow Camp, 7,600', 8/11/81.

Packard 314, WS, dry open flat near Hibbs Cow Camp, 6/28/37.

Physaria didymocarpa (Hook.) Gray, Common Twinpod.

Scarce (mostly at lower elevs.), southern Seven Devils, 5,000' ±.

*Christ 11074, ?NY, mountainside in Snake River Gorge west of Cuprum, 5/30/40.

Physaria oregana Wats., Oregon Twinpod.

Occasional (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000' ±.

Bingham and Miller 475, ID, open, south-facing, rocky hillside with a grass-forb stand along the west fork Rapid River trail 113 just west of the main forks in sec. 26, 2,850', 6/8/82.

Meyer 1616, WS, dry, exposed, southern talus slope 2 mi from the Snake River (in lower Sheep Cr.), 5,500', 5/11/39.

Packard 574, WS, dry, exposed, southern talus slopes above the Clark's Fk. of Sheep Cr., ? elev., 5/13/39.

Rorippa curvisiliqua (Hook.) Bessey, Western Yellowcress.

Uncommon, central and southern Seven Devils, 7,200-8,000'.

Bingham 320, ID, northwest shore of Black Lake, 7,200', 7/17/81.

*Christ 12729, ?NY, in marsh, Sheep Cr. Swamp, 7/17/41.

Packard 296, WS, woods below Hibbs Cow Camp near the head of the north fork of Little Granite Cr., 7,300', 6/26/37.

Plus 2 Bingham and Miller Sight Records: near mouth of Dog Lake, 8,000', 7/28/81; and drawn down shores of Quad Lake, 7,400', 8/14/81.

Rorippa nasturtium-aquaticum (L.) Schinz and Thell., Water Cress (European introduction).

Scarce, lower Rapid River only, 2,400' ±.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 ca. ¼ mi above Blue Gulch, 2,400', 6/8/82.

Rorippa obtusa (Nutt.) Britt., Blunt-leaved Yellowcress.

Scarce, central Seven Devils, 7,200' ±.

Bingham and Miller 442, ID and WS, northeast shore of Ruth Lake where drawn down, 7,200', 8/17/81.

Sisymbrium altissimum L., Jim Hill Mustard (European weed).

Scarce (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000' ±.

Bingham and Miller Sight Records: at Sawpit Saddle, 5,000', 7/8/81; and along the lower Rapid River trail 113 just above the Circle C State Fish Hatchery trailhead gate, 2,250', 6/8/82.

Thelypodium laciniatum (Hook.) Endl. var. *milleflorum* (Nels.) Pays., the white-sepaled variety of the Thick-leaved Thelypody.

Scarce, lower Rapid River only, 2,400' ±.

Bingham and Miller Sight Record, ca. 1¼ mi up the lower Rapid River trail 113 from the Circle C State Fish Hatchery trailhead gate, 2,400', 6/8/82.

Thlaspi montanum L. var. *montanum*, the glaucous variety of Fendler's Pennycress (Syn. *T. fendleri* Gray var. *glaucum* (Nels.) Hitchc.).

Common, entire Seven Devils and west fork Rapid River, 5,000-8,000'.

Aldrich 7/04/07, ID 2264, Camp Howard (prob. the Cow Camp), 7/04/07.

Baker 12265, ID, dry, gravelly west slope of Heavens Gate, 7/31/54.

Bingham and Miller 54, ID, and 114 and Bingham 468, ID and WS, southwest-facing sedge-covered, open, rocky slope in an op *Abies lasiocarpa* forest, ca. 50' above the east Shore of Sheep Lake, 7,875', 7/23/79; gentle southeast-facing, gravelly-loam slope in an open *Abies lasiocarpa-Pinus albicaulis* forest ca. 0.1 mi northeast of Windy Saddle, 7,600', 7/14/80; and west southwest-facing, half-open, moderately moist, cutover slope with a deep black soil, *Pseudotsuga menziesii-Pinus ponderosa* forest, ca. 0.2 mi southwards along rd. 420 from Kirkwood Corrals, 5,120', 5/25/82; respectively.

Brewer 10, Council R.D., Granite Cr., sec. 11, T. 22 (?21) N., R. 2 W., White cabin, ', 6/26/28 (prob. in the Granite Fk. of the Lake Fk. of the Rapid River in T. 21 N.).

Christ 12578, ID, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Q. Jones 213, ID and WS, loose, rocky soil on nearly barren hillside, Heavens Gate, 7/13/50.

Munro 73, WS, ridge at foot of Seven Devils Mts., 6,000', 5/14/37.

Packard 332, WS, moist soil near McGaffee Cow Camp, 5,400', 6/29/37.

Tisdale 7/16/79, IDF 81145, Bald Mt., 7,700', 7/16/79.

Plus 20 Sight Records by Bingham and Miller.

Campanulaceae

Campanula parryi Gray var. *idahoensis* McVaugh, Parry's Bluebell.

Uncommon, central and high southern Seven Devils, 7,500-8,400'.

Christ 12536, ID, in tundra on peak, Heavens Gate, 7/12/41.

*Christ 8684, 12577, and 12645, ?NY, in crags under ridges on Pyramid Peak (south-southwest of Black Lake), 8/8/37; talus slopes in cirque below Seven Devils Lake, 7/13/41; and ledge of cliff above Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41.

LaZelle 13, ID, rocky, east-facing talus slope on west side of Seven Devils Lake, 7,500', 8/29/63.

Steele 935, BOIS, Heavens Gate, 8,400', 8/8/74.

Taylor 1667, WWB, above Sheep Lake, 9/17/67.

Campanula rotundifolia L., Scotch Bluebell.

Scarce, central Seven Devils (usually at elevs. below 5,000'), 7,500-?9,000' +.

Bingham and Miller 448, ID, open, rocky east-facing slope with a good forb stand, along the Horse Heaven Lake manway ca. 0.1 mi below the lake, 7,500', 7/18/81.

*Nelson and Nelson 2961a, ?RM, (depauperate) summit of He Devil, 8/10-15/38 (unable to verify the identity of this collection at RM, since apparently out on loan).

Plus 2 Sight Records by Bingham and Miller, Hanson Cr. and Joes Gap, 6,800-8,000'.

*******Campanula scabrella* Engelm., Rough Hairbell.

Rare, central and eastern Seven Devils, 7,600-8,000', (recommended for a "State Watch List" of plants rare in Idaho but not threatened unless major changes occur in local land use, cf. Steele and others 1981).

?Bingham and Miller 355, ID, rocky, west-facing slope in open *Pinus albicaulis*/*Abies lasiocarpa* stand, east of Mirror Lake, 8,000', 7/26/81 (needs to be verified, but out on loan from ID).

Kruckeberg 3182, ID, NY, ORE, UTC, WS, steep, north-facing, metamorphic cliffs at end of rd. to Seven Devils from Riggins (prob. at Windy Saddle), 7/30/52.

Wellner 1680, ID and IDF, Summit of Pollock Mt., north end, 8,050', 8/6/78.

Campanula uniflora L., Arctic Bluebell.

Occasional, central Seven Devils, 7,600-9,000'.

Ownbey and Meyer 2090, WS, rock crevices, exposed rocky slope, headwaters of Sheep Cr., 6/26/40.

Packard 460, WS, on the Brundage Trail, on the ridge between the forks of Sheep Cr., 7,600', 7/28/38.

St. John and Mullen 8546, WS, rockslide on He Devil Mt., 9,000', 7/24/27.

Caprifoliaceae

Linnaea borealis L. var. *longifolia* Torr., Twinflower.

Uncommon, entire Seven Devils and Rapid River, 5,000-6,200'.

Baird 8/9/71, Council R.D., on stream Flat halfway through the Landore-Cuprum rd. (105), 5,000', 8/9/71.

Baker 12096, ID, shady woods 11 mi west of Riggins (prob. on McClinery Ridge along rd. 517), 7/31/54.

Bingham and Miller Sight Records: along rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82; and along the west fork Rapid River trail 113 near Deep Cr., 4,200', 6/9/82.

C. Johnson Sight Records: Plot 785, along rd. 1819 ca. 0.1 mi southwest of Buckhorn Spring, 6,230', 5/25/82; and Plot 790, along rd. 2060 just east of Kirkwood Cr., 5,300', 6/29/82.

Lonicera involucrata (Richards.) Banks var. *involucrata*, Black Twinberry.

Common, entire Seven Devils, 6,000-7,800'.

Baker 11328, ID, 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham and Miller 134, ID and WS, south side of Dog Cr. 3/5 mi below Dog Lake, 7,600', 7/16/80.

Christ 12638, ID, banks of Sheep Cr. Lakes No. 2 (Shelf Lake), 7/16/41.

Ownbey and Meyer 2078, WS, headwaters of Sheep Cr., 6/26/40.

Packard 349, WS, banks of 1st Sheep Cr. Lake (Basin Lake), 7,500', 6/29/37.

St. John and Mullen 8478, WS, creek bank near Dry Diggins, 7,300', 7/20/27.

Plus 27 Sight Records by Bingham and Miller and C. Johnson.

Lonicera utahensis Wats., Utah Honeysuckle.

Abundant, entire Seven Devils and west fork Rapid River, 5,000-8,100'.

Baird 8/1/71, Council R.D., in timber 1 mi above Bear Guard Station, 5,200', 8/1/71.

Baker 12025 and 12086, ID, open alpine slopes, Seven Devils Camp, 7/21/54; and steep rocky bank below Heavens Gate, 7/21/54; respectively.

Bingham and Miller 178, ID and WS, open, east-facing, *Pseudotsuga menziesii* forest along the Old Boise Trail 101 ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

*Christ 8597 and 12694, ?NY, timbered mountainside 6 mi north of Bear, 8/8/37; timbered mountainside with Douglas-fir, along Sheep Cr. Trail, 7/17/41; respectively.

Cusick 2231, WS, Seven Devils Mts., 7,000' (from the elev., coll. and date prob. along rd. 106 near the Peacock Mines), 7/10/1899.

St. John and Mullen 8549, WS, Little Granite Cr. Lake, 8,000' (prob. He Devil or Triangle Lakes, or the unnamed lake in the head of the Echo Lakes chain), 7/24/27.

Plus 60 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Sambucus cerulea Raf., Blue Elder.

Frequent (mostly at lower elevs.), northern and central Seven Devils and Rapid River, 5,000-6,800'.

Bingham and Miller Sight Records, vicinities of Cold Springs Lookout, Cow Cr. Saddle, Big Canyon Saddle, jct. of trails 101 and 52, Sawpit Saddle, Blue Gulch on lower Rapid River, rd. 517 above its 2d crossing of Papoose Cr. in sec. 26, near the jct. of rds. 1819 and 2060, along rd. 672 northeast of Cow Cr. Saddle, and near the forks of the Rapid River in sec. 26, 5,000-6,800'.

*Nelson and Nelson 2959, ?RM, Rapid River trail (?No.), 8/10-15/38.

Sambucus racemosa L. ssp. *pubens* (Michx.) House, var. *melanocarpa* (Gray) McMinn, the black-fruited variety of the American subspecies of the Black Elderberry.

Common, central and southern Seven Devils, 5,000-7,600'.

Baker 11291, ID, summit of Kinney Point (7,125'), 9/3/53.

Bingham and Miller 131 and 593, ID and WS, and 564, ID, northeast-facing, open, grass-sedge meadow at edge of boulderfield, along the south side of Dog Cr. ca. ½ mi below the Lake, 7,600', 7/16/80; east-facing, open, rocky roadside at the edge of a clearcut forest, on McClinery Ridge along rd. 517 ca. 3.0 mi above its 2d crossing of Papoose Cr. in sec. 26, 5,300', 8/17/82; and along rd. 517 ca. ¼ mi up the rd. from its 2d crossing of Papoose Cr. in sec. 26, roadside clearing, 4,600', 8/17/82; respectively.

Brewer 115, Council R.D., Helena Ranger Station, sec. 12, T. 21 N., R. 3 W. (presumably at old Helena near the Peacock Mines), 6,500', 8/8/30.

Christ 12584, ID, cliffs in the cirque below Seven Devils Lake, 7/13/41.

St. John and Mullen 8488, WS, rocky ridgetop, Dry Diggins Area, 6,500', 7/20/27.

Plus 18 Sight Records by Bingham and Miller.

Symphoricarpus albus (L.) Blake var. *laevigatus* Fern., the Pacific Slope phase of the Common Snowberry.

Common, entire Seven Devils and Rapid River, 5,000-7,200'.

Baker 11992, ID, open woods, Seven Devils rd. (517) 4 mi west of Riggins (prob. in Papoose Cr., ? elev.), 7/21/54.

?Brewer 35, IDF, Patrolman Cr., sec. 1, T. 22 N., R. 2 W. (a small west fork Rapid River Drainage north of Jackley Mt.) 7,000', 8/30/38 (flowers or fruits lacking).

Plus 27 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Huntley Gulch, 5,000-7,200'.

Symphoricarpus oreophilus Gray var. *utahensis* (Rydb.) Nels., Mountain Snowberry.

Frequent, entire Seven Devils, 5,600-8,300'.

Baker 12043 and 12092, ID, open alpine slopes, Seven Devils Camp, 7/21/54; and steep banks below Heavens Gate, 7/21/54; respectively.

Bingham and Miller 373 and Bingham 549, ID, southeast-facing, open, moderately dry, rocky slope in an open *Pseudotsuga menziesii* forest, ca. ¼ mi northeast of the Seven Devils Lake fork of Bridge Cr. along the Old Boise Trail 101, 6,700', 7/27/81; and open, rocky ridgetop with a grass-sedge-forb stand ca. 200' north of Grave Point Lookout tower, 5,630', 7/21/82; respectively.

*Christ 11077, ?NY, on hillsides with yellow pine, Cuprum, 5/30/40.

F. Johnson 7/31/64, IDF 6440, mule pasture below Heavens Gate Lookout, 7,000', 7/31/64.

Plus 9 Sight Records by Bingham and Miller, C. Johnson, and Steele, 1 mi south of Cold Springs Lookout to Bear-Indian Crs. divide, 5,100-7,500'.

aryophyllaceae

Arenaria aculeata Wats., Needle-leaf Sandwort.

Abundant, entire Seven Devils, 5,000-8,500'.

Baird 7/29/71, Council R.D., open ridge at trailhead to Horse Heaven (? jct. trails 214 and 218), 7,500', 7/29/71.

Baker 11306 and 12053, ID, moist, gravelly soil, Sheep Rock, 9/3/53; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 26, ID, and 217, ID and WS, in an open *Pinus albicaulis/Abies lasiocarpa* stand on a rocky ridgetop ca. 0.1 mi southwest of Heavens Gate Lookout, 8,400', 7/21/79; and in the rimrock at the east of the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. Line, 7,850', 8/25/80; respectively.

Christ 12502, ID and WS, rock outcrops and shallow open slopes, Seven Devils Camp, 7/12/41.

Holmgren and Tillett 9595, WS, among rocks, Kinney Point, 8 mi north of Cuprum, 8/14/53.

Q. Jones 201, ID and WS, forming dense mats on rocky slopes, Heavens Gate, 7/12/50.

*Nelson and Nelson 3008, ?RM, Dry Diggins Lookout, 8/10-15/38.

Ownbey and Meyer 2096, WS, gravelly soil, Heavens Gate, 6/27/40.

Wellner 1684, ID, summit of Pollock Mt. north of the Lookout, 8,050', 8/6/78.

Plus 36 Sight Records by Bingham and Miller and C. Johnson.

?*Arenaria capillaris* Poir. var. *americana* (Mag.) Davis, Mountain Sandwort.

*Packard 336, ?WS, exposed outcropping, Hibbs Cow Camp, 7,800', 6/29/37.

*St. John and Mullen 8534, ?WS, rocky ridge, Dry Diggins, 8,000', 7/22/27.

These 2 collections, plus Christ 12502 and Q. Jones 201, above, originally were identified as *A. capillaris*, but because of the overwhelming presence of *A. aculeata*, the small leaf length differences that separate the species, and the generally more northerly distribution of *A. capillaris*, both may be reidentified as *A. aculeata*. Unfortunately both are missing at WS and are not deposited under *A. aculeata*.

Arenaria congesta Nutt. var. *cephaloidea* (Rydb.) Mag., the acute-sepaled, capitate-flowered variety of Ballhead Sandwort.

Scarce, northern Seven Devils, 5,000' ±.

Bingham 294, ID, open *Festuca idahoensis/Koeleria cristata* grassland at Sawpit Saddle, 5,050', 7/8/81.

Arenaria congesta Nutt. var. *congesta*, Ballhead Sandwort.

Uncommon to frequent, northern and central Seven Devils, 5,500-7,600

Baker 12006 and 12083, ID, open alpine slopes, Seven Devils Cam 7/21/54; and dry, gravelly soil on a point above Seven Devils Guard Station, 7/21/54; respectively.

Davis 2236, WS, dry rocky hillside, Grave Point Lookout, 6/24/40.

St. John and Mullen 8457, IDF and WS, gravel ridge, Dry Diggins 7,000', 7/20/27.

Plus 7 C. Johnson Sight Records.

Arenaria congesta Nutt. var. undet., Ballhead Sandwort.

*Christ 8671, ?NY, talus slopes on Pyramid Peak (south-southwes of Black Lake), 8/8/37.

Plus 8 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Grave Point Lookout to Pyramid Peak, 5,200-7,800'.

Arenaria macrophylla Hook., Bigleaf Sandwort.

Abundant, entire Seven Devils and Rapid River, 5,000-7,800'.

Bingham and Miller 123, ID, under an *Abies lasiocarpa/Picea engelmannii* forest just west of the Old Boise Trail 101 at Hanson Cr., 6,800', 7/16/80.

Christ 12566, ID and WS, timbered west slopes, Heavens Gate, 7/12/41.

Davis 2298, WS, bottom of Sheep Cr. under Douglas-Fir, 6/26/40.

Wellner and Bingham 1696, ID, north shore of Echo Lake, 7,200', 8/22/78.

Plus 38 Sight Records by Bingham and Miller, C. Johnson and Steele, Big Canyon Saddle to Huntley Gulch, 5,000-7,800'.

Arenaria obtusiloba (Rydb.) Fern., Arctic Sandwort.

Scarce, central Seven Devils, 8,000-9,000'.

*Christ 12659, ?NY, soil pockets on talus slopes, Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41.

St. John and Mullen 8543, WS, tufts in rock chimney, He Devil Mt., 9,000', 7/24/27.

Arenaria rossii R. Br. var. undet., Ross' Sandwort.

Scarce, central Seven Devils, 7,300-7,600'.

*Christ 12493, ?NY, on banks of rill, Hibbs Cow Camp, 7/11/41.

Arenaria serpyllifolia L., Thyme-leaved Sandwort.

Uncommon, northern Seven Devils, 5,200-5,900'.

Davis 2289, WS, moist draw 1 mi below Grave Point Lookout, 6/25/40.

St. John and Mullen 8341, WS, rocky cleft at head of Bernard Cr., 5,600', 7/19/27.

Plus 3 Sight Records by C. Johnson, Caribou Cr., Grave Point Lookout and McGaffee Cow Camp, 5,250-5,900'.

Cerastium arvensis L., the montane form of Field Chickweed.

Common, northern and central Seven Devils, 5,000-9,000'.

Baker 12263, ID, dry, gravelly hillside, west slope of Heavens

Gate, 7/31/54.

Bingham and Miller 6 and 101, ID, in rocky soil at base of large boulders at foot of cliff immediately north of Heavens Gate Lookout, 8,380', 7/21/79; and in soil pockets under and around boulders on bedrock ridgetop ca. ¼ mi west of the summit of He Devil Mt., 9,000', 7/26/79; respectively.

Christ 12557, ID and WS, grassy ridge, Heavens Gate, 7/12/41.

Q. Jones 226, ID and WS, grassy slopes beneath *Pinus albicaulis*, Heavens Gate, 7/13/50.

Plus 25 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Big Canyon Saddle to south of Rankin Mill, 5,000-7,800'.

Dianthus armeria L., Grass Pink (escaped European garden species).

Scarce, central Seven Devils, 5,000-7,600'.

Bingham and Miller 198, ID, and 577, ID and WS, on open, grassy slopes ca. 0.1 mi east of Windy Saddle, 7,600', 7/13/80; and along the side of rd. 517 ca. ¼ mi above the road's 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82; respectively.

Sagina occidentalis Wats., Western Pearlwort.

Scarce, central Seven Devils, 8,000' ±.

Baker 12267, ID, dry, gravelly hillside on the west slope of Heavens Gate, 7/31/54.

Silene douglasii Hook. var. *douglasii*, Douglas Campion.

Frequent, central and southern Seven Devils, 5,000-7,800'.

Baker 11293, 11994, and 12074, ID, summit of Kinney Point, 9/3/53; Seven Devils rd. 4 mi west of Riggins (prob. along rd. 517 in Papoose Cr.), ? elev., 7/21/54; and rocky point above Seven Devils Guard Station, 7/21/54; respectively.

Bingham and Miller 254, 383, and 410, ID and WS, northwest-facing, open, rocky slope along trail 124 ca. 1 mi north of Horse Heaven Saddle, at the bottom of the switchbacks in the head of the south fork of Devils Farm Cr., 7,800', 8/28/80; south-facing, open, rock crevices ca. ½ mi up the Hanson Lakes manway from the Old Boise Trail 101, 7,300', 7/29/81; and north-facing, 1/5-shaded, rocky slope in an *Abies lasiocarpa-Pinus albicaulis* forest along trail 112 ca. ¼ mi westward from the summit between the forks of Sheep Cr., 7,800', 8/10/81; respectively.

*Christ 8700, ?NY, grassed talus slopes near Black Lake, 8/8/37.

*Kruckeberg 3180, ?WTU, dry, rocky, south-facing slopes at the Saddle at the end of the Seven Devils rd. (rd. 517 at Windy Saddle), 7,500', 7/30/52.

*Nelson and Nelson 2986, ?RM, Horse Heaven, 8/10-15/38.

Plus 4 Sight Records by Bingham and Miller.

Silene oregana Wats., Oregon Campion.

Frequent, northern and central Seven Devils, 5,500-8,000'.

Bingham and Miller 356 and 429, ID, east-facing, open, steep rocky streambank in an open *Abies lasiocarpa-Picea engelmannii* stand ca. ¼ mi below the outlet of Mirror Lake, 7,700', 7/26/81; and west-facing, open moderately dry rocky slope with a sedge-grass-forb stand in an open *Pinus contorta-Abies lasiocarpa* forest along the Dry Diggins Ridge trail 140 ca. 0.1 mi north of the Iron Phone at the jct. of trails 112, 140, and 57, 7,360', 8/12/81; respectively.

Davis 2349, WS, medium dry open hillside, Heavens Gate, 6/27/40.

C. Johnson 8/14/83, BKR 2482, Plot 7036, *Festuca idahoensis-Koeleria cristata* community, east of the Old Boise Trail 101 ca. 1/3 mi south of The Narrows, 7,660', 8/14/83.

*Kruckeberg 3181, ?WTU, dry, rocky, south-facing slopes at the saddle at the end of the Seven Devils rd. (rd. 517 at Windy Saddle), 7,500', 7/30/52.

Kruckeberg 3203, WS and WTU, on rocky slopes and in crevices just below Dry Diggins Lookout, 8/1/52.

St. John and Mullen 8436, WS, grassy head of Bernard Cr., 5,500', 7/19/27.

Tisdale 7/11/79, IDF 81129, 1½ mi west of Cold Springs Lookout, 6,600', 7/11/79.

Plus 6 Sight Records by Bingham and Miller and C. Johnson.

Silene parryi (Wats.) Hitchc. and Mag., Parry's Campion.

Scarce, northern Seven Devils, 5,600' ±.

Bingham 552, ID, open rocky ridgetop with a basalt-derived soil and an open grass-forb-sedge stand plus a few shrubs, ca. 150' northeast of Grave Point Lookout tower, 5,630', 7/21/82.

Silene scouleri Hook. var. *scouleri*, Scouler's Campion.

Uncommon, northern and central Seven Devils, 5,600-8,300'.

*Christ 12514, ?NY, open, grassy mountainside 1 mi east of Seven Devils Camp, 7/12/41.

Davis 2342, WS, dry hillside, Grave Point Lookout, 6/24/40.

Plus 6 Bingham and Miller and Tisdale Sight Records, Cold Springs Cow Camp to Ruth Lake, 6,600-7,600'.

Spergularia rubra (L.) Presl, Red Sandspurry (European introduction).

Uncommon, northern and central Seven Devils, 6,500-7,600'.

Baker 12081, ID, gravelly soil on a point above Seven Devils Guard Station, 7/21/54.

Bingham 285, ID, drawn-down north bank of Crater Lake, 6,550', 7/9/81.

Plus 3 Sight Records by Bingham and Miller, drawn-down shore of Horse Heaven Lake, 7,600', 8/18/81; basalt scabrock just northwest of Lily Pad Lake, 7,300', 8/11/81; and along the Old Boise Trail 101 ca. 0.1 mi north of the Cannon Lake trail, 6,500', 7/27/81.

Stellaria calycantha (Ledeb.) Bong. var. *bongardiana* Fern., the variety of Northern Starwort having few-flowered cymes.

Scarce, northern and central Seven Devils, 5,400-7,300'.

Bingham 299, ID, gentle south-facing, grassy, forested hillside with a deep sandy loam soil, under *Pinus ponderosa* and *Pseudotsuga menziesii* at the end of the Low Saddle spur rd. at Low Saddle campground, 5,400', 7/8/80.

Bingham and Miller Sight Record, along the Dry Diggins Ridge trail 140 ca. ¼ mi south of the drop-off at the north end of the Ridge-plateau, 7,300', 8/12/81.

?*Stellaria crassifolia* Ehrb., Thick-leaved Starwort.

Bingham and Miller 445, ID and WS, gentle, north-facing, 1/3-open, bedrock slope, soil pocket in small forest opening in a *Picea engelmannii, Pinus albicaulis, Abies lasiocarpa* forest 30' above the south bank of Ruth Lake, 7,250', 8/17/81 (keys with difficulty).

?*Stellaria crispa* Cham. and Schlecht., Crisped Starwort.

*Christ 8633 and 12661, ?NY, springy places on mountainside, Black Lake, 8/8/37; and edge of spring, Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41; respectively (but the geog. range of *S. crispa* does not include west central Idaho).

Stellaria media (L.) Cyrill., Chickweed (European weed).

Occasional, northern and central Seven Devils and Rapid River, 5,000-6,650'.

Bingham and Miller 389, ID and WS, gentle, south-facing, 4/5-open rocky slope at the edge of a *Pseudotsuga menziesii* forest ca. ¼ mi up the Cannon Lake trail from the Old Boise Trail 101, 6,650', 7/27/81.

Bingham and Miller Sight Records: along the stock-drive part of trail 104 ca. 0.1 mi east of Big Canyon Saddle, 4,900', 6/11/82; and along trail 113 in the lower Rapid River, 1¼ mi above the Hatchery, 2,400', 6/8/82.

Stellaria nitens Nutt., Shining Chickweed.

Scarce, northern Seven Devils, 5,000-5,200'.

?Bingham and Miller 509, ID and WS, southeast-facing, open, rocky hillside in an open grass-forb stand of the *Festuca idahoensis-Agropyron spicatum* h.t., along trail 104 ca. 150' north of Big Canyon Saddle, 5,050', 6/11/82 (but the stem is leafy full length).

Tisdale Sight Record, vicinity of Low Saddle, 5,200', 7/13/78.

Stellaria obtusa Engelm., Blunt-sepaled Starwort.

Scarce, southern Seven Devils, 7,200' ±.

*Christ 8641, ?NY, shore of Black Lake, 8/8/37.

elastraceae

Glossopetalon nevadense Gray, Spiny Greenbush.

Scarce, Rapid River only, 2,200-2,500'.

Bingham and Miller Sight Record, ca. ¼ mi up the lower Rapid River trail 113 from the Circle C State Fish Hatchery trailhead gate, 2,300', 6/8/82.

Pachistima myrsinites (Pursh) Raf., Mountain Lover or Mountain Box.

Occasional, central and southern Seven Devils, 5,500-6,400'.

Baird 8/18/71, Council R.D., in timber 2 mi south of Landore, 5,500', 8/18/71.

Bingham and Miller 604, ID and WS, east-facing rocky hillside with a dense *Abies grandis-Pseudotsuga menziesii* forest, along the east fork Sheep Cr. trail 58 ca. 3/4 mi north of its jct. with trail 112 northwest of Windy Saddle, 6,350', 8/18/82.

Steele Sight Records: Stand 81-Pa-01A, along the Indian Cr. rd. ca. 6 mi above Cuprum, 5,550', 6/24/81; and the companion Stand 81-Pa-01B, of the same locality, elev., and date.

enopodiaceae

Chenopodium album L., Lambsquarter (Eurasian introduction).

Scarce, central Seven Devils and Rapid River, 5,000-7,900'.

Bingham and Miller 387, ID, in the disturbed trail tread along the Old Boise Trail ca. 1/3 mi north of the Heavens Gate parking area, 7,880', 7/30/81.

Plus 1 Sight Record by Bingham and Miller, ca. ½ mi up the lower Rapid River trail 113 from the trailhead gate at the Circle C State Fish Hatchery, 2,300', 6/8/82.

Monolepis nuttalliana (Schultes) Greene, Patata.

Scarce, central Seven Devils, 7,300' ±.

Baker 12073, ID, dry, rocky banks above Seven Devils Guard Station, 7/21/54.

nvolvulaceae

Convolvulus arvensis L., Field Morning Glory or Bindweed (European introduction).

Scarce, Rapid River only, 4,000' ±.

Brewer 73, Council R.D., mouth of Paradise Cr. (on main Rapid River), sec. 15 (?27), T. 22 N., R. 1 W., 4,500', 7/30/29.

Bingham and Miller Sight Record, along the west fork of the Rapid River trail 113 in the McCrea Place pasture, 4,000', 6/9/82.

naceae

Cornus stolonifera Michx. var. *stolonifera*, Red Osier Dogwood.

Uncommon (mostly at lower elevs.), entire Seven Devils and Rapid River, 5,000-5,400'.

Bingham and Miller 602, ID and WS, mature, dense, stream bottom stand of *Abies grandis* and *Picea engelmannii* along the bottom of the east fork of Sheep Cr. at the unnamed creek ca. 1 mi south of Log Cr., 5,100', 8/18/82.

Plus 4 Sight Records by Bingham and Miller, McGaffee Cow Camp, Old Landore, and lower and west fork of the Rapid River, 2,400-5,700'.

sulaceae

Sedum lanceolatum, Torr. var. *lanceolatum*, Lance-leaved Sedum.

Common, entire Seven Devils and Rapid River, 5,000-9,400'.

Bingham and Miller 8, 50, and 96, ID, and 212, ID and WS, west-facing, open, rocky slope in an open *Abies lasiocarpa-Pinus albicaulis* forest, just above the roadbank of the Heavens Gate rd. ca. ½ mi below the parking area, 8,180', 7/21/79; north-facing, open, bedrock ridgetop on She Devil Mt. ca. 0.2 mi south of the She Devil - Tower-of-Babel Saddle, 9,050', 7/23/79; open bedrock bench ca. 50' south and 25' below the summit of He Devil Mt., 9,370', 7/26/79; and north-facing rocky ridgetop with a sedge-forb meadow in an opening in an *Abies lasiocarpa-Pinus albicaulis* stand, ca. 0.1 mi northwards along the Old Boise Trail from the Horse Heaven Lookout cabin, 8,150', 8/25/80; respectively.

Packard 462, WS, moist crevices on talus slopes on the ridge between the forks of Sheep Cr. (along trail 112), 7,500', 7/28/38.

Wellner 1694, ID, east-facing slope at Sheep Lake, 8,000', 8/21/78.

Plus 32 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to Lockwood Saddle, 5,000-8,000'.

Sedum leibergii Britt., Leiberg's Sedum.

Scarce, lower Rapid River only, 2,500' ±.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 ca. 3/4 mi above Blue Gulch, 2,500', 6/8/82.

Sedum rosea (L.) Scop., King's Crown or Rosewort.

Uncommon, central Seven Devils, 7,300-9,300'.

Bingham and Miller 47, ID, open, west-facing, bedrock crevices ca. 150' north of the summit of She Devil Mt., 9,275', 7/23/79.

*Christ 12445, 12492, and 12580, ?NY, moist cliffs above Seven Devils Lake, 7/11/41; summit of He Devil Mt. (courtesy of hikers returning from ascent), 7/11/41; and on cliffs in cirque below Seven Devils Lake, 7/13/41; respectively.

Packard 304, WS, on moist, rocky soil near Sheep Lake, 8,800' (lake elev. is 7,825'), 6/27/37.

St. John and Mullen 8565, WS, crevice on rock slide on He Devil Mt., 9,000', 7/24/27.

Plus 3 Sight Records by Bingham and Miller, Goat Pass, cliffs on south side of Basin Lake, and cliffs along the south side of Seven Devils Lake, 7,300-8,300'.

Sedum stenopetalum Pursh, Wormleaf Sedum.

Frequent, entire Seven Devils, 5,100-7,800'.

Baker 12013, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Brewer 70, Council R.D., Iron Springs (camp ca. 0.2 mi north of Holbrook Saddle), sec. 24, T. 22 N., R. 3 (?2) W., 6,500', 7/20/29.

*Christ 12574, ?NY, rock outcrops, Seven Devils Camp, 7/13/41.

C. Johnson 8/10/83, BKR 2488, Plot 7014, *Festuca idahoensis-Carex hoodii* community, east of trail 124 ca. ¼ mi south-southwest of the summit of Potato Hill, 7,750', 8/10/83.

Plus 6 Sight Records by C. Johnson, Steele, and Tisdale, Cold Springs Lookout south to the Bear-Indian Cr. divide along rd. 002, 5,800-7,600'.

Cupressaceae

Juniperus communis L. var. *montana* Ait., Mountain Juniper.

Common, central and southern Seven Devils and Rapid River, 6,000-9,200'.

*Baker 12286, ?ID, open gravelly slopes west of Seven Devils Camp, 7/31/54.

Bingham and Miller 80 and 377, ID, west-facing open forest slope in protected valley, *Pinus albicaulis-Abies lasiocarpa* forest, midslope above small valley ca. 2/5 mi directly north of the summit of He Devil Mt., 8,350', 7/25/79; and cliff crevices on steep north-facing slope, ½-open but shaded by the cliffs, *Abies lasiocarpa-Pinus albicaulis* forest, south side of Seven Devils Lake, 7,600', 7/27/81; respectively.

*Christ 8676 and 12599, ?NY, open ridge on Pyramid Peak, 8/8/37; and slopes in timber in cirque below Seven Devils Lake, 7/13/41; respectively.

Munro 80, WS, ridge south of McGaffee Cow Camp, 5,000' (prob. 5,700-6,000'), 5/14/37.

*Nelson and Nelson 2961, ?RM, summit of He Devil (actually more likely to have been in the saddle just south of the summit), 8/10-15/38.

St. John and Mullen 8513, WS, rocky knoll, Dry Diggins, 8,000', 7/21/27.

Tucker 7/17/32, ID 8789, Rapid River, 7/17/32.

Plus 15 Sight Records by Bingham and Miller.

yperaceae

?*Carex aquatilis* Wahl., Water Sedge.

?Bingham 328, ID, north shore of Black Lake, 7,200', 7/17/81 (immature).

Plus 1 questionable Sight Record by Bingham, banks of the largest and northeasternmost of the lakes in Six Lake Basin, 7,400', 7/18/81.

Carex atrata L. var. *erecta* Boott, the variety of the Blackened Sedge with the broader perigynum.

Scarce, southern Seven Devils, 6,750' ±.

C. Johnson 8/31/83, BKR 2494, Plot 7069, west of the Deep Cr. trail 219 ca. ½ mi north of the Black Lake rd. 112 at High Dive, *Deschampsia cespitosa* meadow community, 6,760', 8/31/83.

Carex concinnoides Mack., Northwest Sedge.

Occasional, lower northern and southern Seven Devils and Rapid River, 5,000-6,400'.

Bingham and Miller 498, ID and WS, grand fir/clintonia h.t. along trail 113 in the west fork of the Rapid River ca. 0.2 mi below trail 62, 4,680', 6/9/82.

Bingham and Miller Sight Records: along rd. 106 north of Lockwood Saddle, 6,400', 6/30/82; and along rd. 672 near China Saddle, 5,200', 6/10/82.

Carex deweyana Schw., Dewey's Sedge.

Scarce, northern Seven Devils, 6,500' ±.

Bingham 286, ID, north bank of Crater Lake, 6,550', 7/9/81.

Carex eurycarpa Holm, Wide-fruited Sedge.

Uncommon, central and southern Seven Devils, 7,000-7,400'.

C. Johnson Sight Records: Plot 7021, east of trail 124 ca. 1 mi south of Hibbs Cow Camp, 7,050', 8/11/83; Plot 7024, west of trail 112 ca. ½ mi south of Hibbs Cow Camp, 8/11/83; Plot 7027, east of the Dry Diggins Ridge trail 140 at the dropoff ca. 2¼ mi north of the jct. of trails 112, 57, and 140 at the Iron Phone, 7,370', 8/12/83; and Plot 7062, north of the trail 217 at the northwest end of the 2d lake proceeding westward along the trail in Six Lake Basin, 7,360', 8/30/83.

Carex foetida Allioni var. *vernacula* (Bailey) Keuk., Foetid Sedge.

Scarce, southern Seven Devils, 7,800' ±.

Baird 7/29/71, Council R.D., partial snowbank at trailhead to Horse Heaven (? jct. trails 214 and 218), 7,500', 7/29/71.

Carex geyeri Boott, Elk Sedge.

Abundant, entire Seven Devils, 5,000-8,400'.

*Christ 12598, ?NY, slopes in timber in cirque below Seven Devils Lake, 7/13/41.

*Hermann 12044, ?NA, Seven Devils rd. (517), 1 mi below Shingle Cr., ca. 6,000', 8/6/55.

*St. John and Mullen 8519, ?WS, Dry Diggins, 7/22/27.

Plus 53 Sight Records by Bingham and Miller, C. Johnson, Tisdale, and Steele, Big Canyon Saddle to Huntley Gulch, 5,000-8,400'.

Carex haydeniana Olney, Hayden's Sedge.
Scarce, central Seven Devils, 7,000-7,600'.
St. John and Mullen 8520, WS, Dry Diggins Area, 7/22/27.

Carex hoodii Boott, Hood's Sedge.
Abundant, entire Seven Devils, 5,200-8,200'.
Bingham and Miller 156 and Bingham 301, ID, sedge/forb meadow in open forest on southeast-facing, gentle, rocky slope, below the Old Boise Trail ca. 0.1 mi northeast of Hanson Cr., 6,800', 7/17/80; and streamside in open forest, jct. rd. 2060 and Meyer Cr., 5,800', 7/8/81; respectively.
*Hermann 12039, ?MICH, ?NA, vicinity of Cold Springs Lookout, 6,900', 8/6/55.
C. Johnson 8/12/83, BKR 2562, Plot 7027, east of the Dry Diggins Ridge trail 140 at the dropoff ca. 2¼ mi north of the Iron Phone (jct. trail 140, 112 and 57), *Festuca idahoensis/ Antennaria* community, 7,370', 8/12/83.
Tisdale 7/15/78, IDF 78350; 7/13/78, IDF 78351; 7/14/78, IDF 78354; Seven Devils Guard Station pasture, 7,300', 7/15/78; 2 mi west of Cold Springs Lookout, 6,700', 7/13/78; and Seven Devils Guard Station pasture, 7,500', 7/14/78; respectively.
Plus 50 Sight Records by Bingham and Miller, C. Johnson and Tisdale, Sawpit Saddle to Black Lake, 5,200-8,200'.

Carex illiota Bailey, Small-headed Sedge.
Scarce, central Seven Devils, 7,000-7,600'.
*St. John and Mullen 8586, ?WS, Dry Diggins, 7/25/27.

Carex lenticularis Michx. var. *lenticularis*, Lenticular-achened Sedge.
Uncommon, central Seven Devils, 7,100-7,600', mostly on lake shores.
Bingham and Miller 232, ID and WS, banks of Ruth Lake, just north of the east outlet, 7,200', 8/27/80.
Plus 7 Sight Records by Bingham and Miller, Bernard Lakes to Ruth Lake, 7,100-7,600'.

Carex leporinella Mack., Sierra Hare Sedge.
Scarce, summits of highest, central Seven Devils peaks, 9,000-9,400'.
Bingham and Miller 48 and 92, ID, west-facing bedrock crevices ca. 150' north of the summit of She Devil Mt., 9,275', 7/23/79; and crevices in bedrock bench ca. 10' south and below summit of He Devil Mt., 9,385', 7/26/79; respectively.

Carex microptera Mack., Small-winged Sedge.
Uncommon, central and southern Seven Devils, 6,600-9,000' ±.
Bingham 287, ID, banks of Crater Lake, 6,650', 7/9/81.
Brewer 112, Council R.D., sec. 36, T. 22 N., R. 2 W. (prob. along trail 191 east of Black Lake), 7,000', 8/18/30.
*Nelson and Nelson 3014, ?RM, top of He Devil, 8/10-15/38.
Plus 6 Sight Records by Bingham and Miller, and C. Johnson, Papoose Lake to High Dive, 6,600-7,200'.

Carex multicostata Mack., Many-ribbed Sedge.
Uncommon, northern and central Seven Devils, 6,700-8,000' +.
*Hermann 12038, ?MICH, ?US, vicinity of Cold Springs Lookout, 6,900', 8/6/55.
C. Johnson 8/12/83, BKR 2561, Plot 7027, east of the Dry Diggins Ridge trail 140 at the dropoff 2¼ mi north of the Iron Phone (junction trail 140, 112, and 57), *Festuca idahoensis/Antennaria* community, 7,370', 8/12/83.
Plus 3 Sight Records by C. Johnson, southwest of Cold Springs Cow Camp, Horse Heaven Lookout pasture, and Potato Hill, 6,700-8,040'.

Carex nigricans C. A. Meyer, Black Alpine Sedge.
Occasional, central and southern Seven Devils, 7,500-8,000'.
*Christ 8619, 8660, and 8687, ?NY, tundra on high mountainside, Black Lake, 8/8/37; meadow in cirque, Pyramid Peak (south-southwest of Black Lake), 8/8/37; and in tundra in cirque, Black Lake, 8/8/37, respectively.
*St. John and Mullen 8585, ?WS, Dry Diggins, 7/25/27.

Carex pachystachya Cham., Thick-headed Sedge.
Scarce, southern Seven Devils, 7,500-8,000'.
*Christ 8672 and 8681, ?NY, meadow in glacial cirque, Black Lake,

7/7/37; and high meadow near Black Lake, 7/7/37, respectively.

Carex paupercula Michx., Poor Sedge.

Scarce, southern Seven Devils, 8,000' ±.

*Christ 8618, ?NY, high mountainside, Black Lake, 7/7/37.

Carex paysonis Clokey, Payson's Sedge.

Occasional, central and southern Seven Devils, 7,500-8,000'.

Baird 7/29/71, Council R.D., partial snowbank at trailhead to Horse Heaven (? jct. trail, 214 and 218), 7,500', 7/29/71.

Bingham 346, ID, and Bingham and Miller 433, ID and WS, wet slopes below melting snowbanks in an *Abies lasiocarpa/Pinus albicaulis* forest, at Joes Gap along trail 217, 8,000', 7/18/81; and north-facing, open rocky slope in an *Abies lasiocarpa/Pinus albicaulis* forest along trail 123 ca. ¼ mi southward from Gem Lake, 8,000', 8/13/81; respectively.

*Christ 8680, ?NY, on slopes and meadow, Black Lake, 8/8/37.

Carex petasata Dewey, Liddon's Sedge.

Occasional, central Seven Devils, 7,500-8,000'.

Christ 12509, ID, open, grassy mountainside, 1 mi east of Seven Devils Camp, 7/12/41.

C. Johnson Sight Records: Plot 7036, 1/3 mi south of The Narrows, 7,660', 8/14/83; Plot 7070, west of the Old Boise Trail at Fire Camp Saddle, 7,180', 9/1/83; and Plot 7076, east of the Heavens Gate Lookout rd. ca. 1/3 mi south of the Lookout parking area, 9/2/83.

Carex phaeocephala Piper, Mt. Hare Sedge.

Occasional, central Seven Devils, 7,400-9,000' ±.

Bingham and Miller 215, ID and WS, open, rocky subalpine ridgetop, sedge-forb stand, immediate vicinity of Horse Heaven Lookout cabin, 8,200', 8/25/80.

*St. John and Mullen 8544, ?WS, He Devil Mt., ? elev., 7/24/27.

Plus 2 Sight Records by Tisdale, Bald Mt. and Seven Devils Guard Station pasture, 7,400-7,800'.

?*Carex raynoldsii* Dewey, Raynold's Sedge.

*St. John and Mullen 8453, ?WS, Dry Diggins, 7/20/27 (presumably central Idaho is not within the distribution of this species).

Carex rossii Boott, Ross' Sedge.

Frequent, central and southern Seven Devils, 5,000-8,200'.

Baird 7/20/72, Council R.D., below Smith Mt. Lookout, 6,500', 7/20/72.

*Nelson and Nelson 3010, ?RM, Dry Diggins, 8/10-15/38.

*St. John and Mullen 8463, ?WS, Dry Diggins Area, 7/20/27.

Plus 16 Sight Records by C. Johnson and Steele, Papoose Lake to Bear-Indian Cr. divide along rd. 002, 5,000-8,000'.

?*Carex scoparia* Schk.

Scarce, central Seven Devils, 7,500' ±.

Packard 351, WS, wet soil near lakeside, 2d Sheep Cr. Lake (Shelf Lake), 6/29/37 (*C. scoparia*, presumably, is from west of the Cascade Mts. only).

Carex scopulorum, Holm, Holm's Rocky Mt. Sedge.

Frequent, central and southern Seven Devils, 6,800-7,800'.

Bingham and Miller 116 and 353, and Bingham 331, ID and WS, bog between Lower Hanson Lake and the pond to its north-northeast, 7,750', 7/15/80; perched marsh in Bridge Cr. ca. ½ mi below Mirror Lake, 7,300', 7/26/81; and northwest shore of Black Lake, 7,200', 7/17/81; respectively.

Packard 340, WS, beside the 2d Sheep Cr. Lake (Shelf Lake), 6/29/27.

*St. John and Mullen 8584, ?WS, Dry Diggins Area, 7/25/27.

Plus 6 Sight Records by Bingham and Miller and C. Johnson, Dry Diggins Ridge to High Dive, 6,800-7,600'.

Carex stipata Muhl., Sawbeak Sedge.

Uncommon, central Seven Devils, 7,000-7,500' (lake banks and wet meadows).

Bingham and Miller Sight Records: banks of Baldy Lake, 7,200', 8/15/81; banks of Lower Cannon Lake, 7,000', 7/27/81;

vernal pond between He Devil and Triangle Lakes, 7,500', 8/14/81; banks of Lily Pad Lake, 7,300', 8/11/81; and along trail 123 in the long, wet sedge meadow between Lily Pad and Basin Lakes, 7,300', 8/13/81.

Eleocharis palustris (L.) Roem. and Schult., Common Spike Rush.
Uncommon, central Seven Devils, 7,200-7,300'.
Bingham and Miller 231, ID and WS, in shallow water at the northeast end of Ruth Lake, 7,200', 8/27/80.
St. John and Mullen 8588, WS, edges of Lily Pad Lake, Dry Diggins, 8,000' (actually the lake lies at 7,300'), 7/25/27.
Plus 3 Sight Records: Bernard, Crater, and Lily Pad Lakes 7,200-7,300', by Bingham and Miller.

Scirpus microcarpus Presl, Small-fruited Bullrush.
Scarce, northern Seven Devils, 6,200' ±.
Bingham 304, ID, west-facing, 1/5-shaded streambank with a moist, deep silty loam soil, at the upper crossing of rd. 1819 over Caribou Cr., 6,200', 7/10/81.

Dipsacaceae

Dipsacus sylvestris Huds., Teasel (European weed).
Scarce (mostly at lower elevs.), central Seven Devils and Rapid River, 5,000' +.
Bingham and Miller Sight Records: vicinity of the Circle C State Fish Hatchery, 2,200', 6/8/82; and along rd. 672 south of China Saddle, 5,200', 6/10/82.

Elaeagnaceae

Shepherdia canadensis (L.) Nutt., Canadian Buffalo-berry.
Scarce, southern Seven Devils, 5,000' ±.
Baird 8/1/71, Council R.D., in timber 1 mi above Bear Guard Station, 5,200', 8/1/71.
*Christ 8591, ?NY, timbered mountainside 6 mi north of Bear, 8/8/37.

Equisetaceae

Equisetum arvense L., Common Horsetail.
Occasional, central Seven Devils and Rapid River, 5,000-6,600'.
Bingham and Miller 366, ID, and 600, ID and WS, in the 2d watere fork of Bridge Cr. ca. 1 mi below Seven Devils Guard Statio along the Old Boise Trail 101, 6,600', 7/27/81; and in a mature *Abies grandis, Picea engelmannii* stand in the bottom of the south fork of Sheep Cr. along trail 58 at the unnamed creek ca. 1 mi south of Log Cr., 5,100', 8/18/82; respectively.
Plus 2 Sight Records by Bingham and Miller, Bernard Lakes and along the lower Rapid River ¼ mi above Blue Gulch, 2,500-5,100'.

Equisetum hyemale L., Common Scouring-rush.
Scarce, lower Rapid River, 2,400' ±.
Bingham and Miller Sight Record, along the lower Rapid River trail 113 near Blue Gulch, 2,400', 6/8/82.

Ericaceae

Chimaphila menziesii (R. Br.) Spreng., Little Princes' Pine.
Occasional, central Seven Devils, 6,400-6,800'.
Bingham and Miller 173, ID, moderately dense *Abies lasiocarpa, Pinus contorta, Pseudotsuga menziesii* forest along the Old Boise Trail 101 ca. 3/4 mi south of Cannon Cr., 6,800', 7/18/80.
*Christ 12627, ?NY, on timbered mountainside with Douglas-fir along the trail from Wilson (Hibbs) Cow Camp to Baldy Lake (prob. the forerunner of trail 124), 7/15/41.

Plus 1 Sight Record by Bingham and Miller, along trail 124 just south of the Baldy Lake trail, 7,000', Aug. 14, 1981.

Chimaphila umbellata (L.) Bart. var. *occidentalis* (Rydb.) Blake, Princes' Pine.

Abundant, entire Seven Devils and Rapid River, 5,000-7,600'.

Baird 8/1/71, Council R.D., ¼ way down Bear-Landore rd. (105), 5,200', 8/1/71.

Bingham and Miller 168, ID and WS, gently sloping, east-facing, silty stream bottom in a moderately dense *Abies lasiocarpa/Picea engelmannii* forest just below the Old Boise Trail at Hanson Cr., 6,700', 7/17/80.

*Christ 12626, ?NY, on timbered mountainside with Douglas-fir along the trail from the Wilson (Hibbs) Cow Camp to Baldy Lake (prob. the forerunner of trail 124), 7/15/41.

Plus 47 Sight Records by Bingham and Miller, C. Johnson, and Steele, Kirkwood Cr. to Landore, 5,200-7,600'.

Gaultheria humifusa (Grah.) Rydb., Wintergreen.

Frequent, central and southern Seven Devils, 6,600-8,000'.

Bingham 326, ID and WS, open lakeshore at edge of moderately dense *Abies lasiocarpa/Picea engelmannii* forest, northwest shore of Black Lake, 7,200', 7/17/81.

Christ 12589, ID and WS, cliffs in cirque below Seven Devils Lake, 7/13/41.

Plus 9 Sight Records by Bingham and Miller, Bernard Lakes and east fork of Sheep Cr. to Six Lake Basin, 6,600-8,000'.

Kalmia microphylla (Hook.) Heller, Alpine Laurel.

Uncommon, central Seven Devils, 7,300-8,500'.

Bingham and Miller 33, ID, in the open marsh at the north end of the pond lying alongside the northeast side of Sheep Lake at the foot of the Goat Pass manway, 7,880', 7/22/79.

*Christ 12653, ?NY, marshy bank of Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41.

Packard 310, WS, border of Sheep Lake below He Devil Mt., 9,000' (actually Lake elev. is 7,875'), 7/27-28/37.

St. John and Mullen 8578, WS, boggy shore of Little Granite Cr. Lake (possibly He Devil, Triangle, or small, unnamed lake above Triangle Lake), 8,500', 7/24/27.

Plus Bingham and Miller Sight Records: north shore of Echo Lake, 7,200', 8/14/81 and on hummocks in shallow water along the east side of Lily Pad Lake, 7,300', 8/11/81.

Ledum glandulosum Nutt. var. *glandulosum*, Mountain Labrador Tea.

Uncommon, central Seven Devils, 7,200-7,400' ±.

Bingham and Miller 241, ID, level, shady, boggy area in the small marsh along the Ruth Lake trail ca. 0.1 mi east of the Lake, 7,200', 8/27/80.

Christ 12667, ID, margins of Sheep Cr. Lake No. 2 (Shelf Lake), 7/16/41.

C. Johnson 8/12/83, BKR 2551, Bernard Lakes, 7,200', 8/12/83.

St. John and Mullen 8591, WS, bank of Lily Pad Lake, 8,000' (lake elev. actually is 7,300'), 7/25/27.

*Taylor 1672, WWB, moist bank of Shelf Lake, 7,430', 9/17/67.

Plus 2 Sight Records by Bingham and Miller (Bernard and Lily Pad Lakes).

Menziesia ferruginea Smith var. *glabella* (Gray) Peck, Inland Fools Huckleberry.

Common, entire Seven Devils and west fork Rapid River, 5,000-7,900'.

Bingham and Miller 180, ID and WS, under a moderately dense *Pinus contorta-Abies lasiocarpa* forest along the Old Boise Trail 101 at the Mirror Lake fork of Bridge Cr., 6,800', 7/18/80.

*Christ 8631 & 12733, ?NY, springy places on mountainside, Black Lake, 8/8/37; and on promontories about Sheep Cr. Lake No. 2 (Shelf Lake), 7/17/41; respectively.

Christ 12581, ID, cliffs in cirque below Seven Devils Lake, 7/13/41.

C. Johnson 8/12/83, BKR 2556, Bernard Lakes, 7,200', 8/12/83.

*Nelson and Nelson 2971, ?RM, Dry Diggins Camp, 8/10-15/38.

St. John and Mullen 8581, WS, near the head of Little Granite Cr. (prob. in head of the Echo Lake fork), 7,500', 7/24/27.

Plus 29 Sight Records by Bingham and Miller, C. Johnson, and Steele, including Black Lake and Six Lake Basin areas.

Phyllodoce empetriformis (Sw.) D. Don, Red Mountain-heather.

Common, central and southern Seven Devils, 7,200-8,400'.

Baird 7/29/71, Council R.D., at base of snowbank ½ mi north of High Dive, 7,500', 7/29/71.

Baker 12275, ID, deep coniferous woods, west slope of Heavens Gate, 7/31/54.

Bingham and Miller 79A, ID, west-facing, rocky, moderately dry opening in an *Abies lasiocarpa, Pinus albicaulis* forest in the valley ca. 0.4 mi directly north of the summit of He Devil Mt., 8,300', 7/25/79 (with *P. glandulifera* (Hook.) Cov., below).

*Christ 8665, 12464, & 12641, ?NY, in tundra in meadow, Pyramid Peak, 8/8/37; on ridges under *Pinus albicaulis*, Seven Devil Ridge, 7/11/41; and ridge above Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41; respectively.

Henderson Sight Record, along trail 123 at the small, vernal Pond on the Gem Lake side between Gem and Sheep Lakes (with *E. glandulifera* and hybrid, below), 8,200', 6/5/77.

*Nelson and Nelson 2994, ?RM, Dry Diggins Lookout, 8/10-15/38.

Packard 340, WS, border of the 4th Sheep Cr. Lake (Sheep Lake), 9,000' (actually the lake elev. is 7,875'), 6/27/37.

St. John and Mullen 8526, WS, alpine meadows, Dry Diggins, 8,000', 7/22/27.

Steele 939, BOIS, just below Heavens Gate (Lookout), 8,400', 8/8/74.

Plus 23 Sight Records by Bingham and Miller and C. Johnson.

X *Phyllodoce intermedia* (Hook.) Camp, Pale Pink Heather (the natural hybrid between Red and Cream Mountain-heather).

Scarce, central Seven Devils, 8,200' ±.

Henderson Sight Record, near the small, vernal pond on the Gem Lake side of trail 123 between Gem and Sheep Lakes (occurring with both parents, *P. empetriformis* and *P. glandulifera*), 8,200', 7/5/77.

Phyllodoce glandulifera (Hook.) Cov., Cream Mountain-heather.

Occasional, central Seven Devils, 8,200-8,500' ±.

Bingham and Miller 79B, ID, west-facing, rocky, moderately dry opening in an *Abies lasiocarpa, Pinus albicaulis* forest in the valley ca. 0.4 mi directly north of the summit of He Devil Mt., 8,300', 7/25/79 (with *P. empetriformis*, above).

Henderson Sight Record, near the vernal pool on the Gem Lake side of trail 123 between Gem and Sheep Lakes, 8,200', 7/5/77 (with both *P. empetriformis* and the hybrid).

St. John and Mullen 8559, WS, rocky ledge, He Devil Mt., 9,000', 7/24/27.

Pterospora andromedia Nutt., Pine Drops.

Uncommon, northern and central Seven Devils and Rapid River, 5,000-6,400'.

Bingham and Miller Sight Records: along rd. 1819 ca. 0.1 mi southeast of the Low Saddle spur rd., 5,900', 7/18/81; alo rd. 517 near the upper crossing of the south fork of Papoo Cr., 6,400', 8/17/82; and along the west fork Rapid River trail 113 ca. ¼ mi below Oxbow Cr., 4,700', 6/9/82.

C. Johnson Sight Record, Plot 7030, along trail 110 on the Sawyer - Beartrap Crs. ridge at the bottom of the 1st switchback from the top, 5,600', 8/11/83.

*St. John and Mullen 8600, ?WS, rock ridge above Sheep Cr., 7,000', 7/26/27.

Pyrola asarifolia Michx. var. *asarifolia*, Alpine Pyrola.

Frequent, entire Seven Devils, 5,200-7,300'.

Baird 8/12/71, Council R.D., on Indian Cr. 1 mi below Landore, 5,200', 8/12/71.

*Baker 12098, ?ID, shady woods 11 mi west of Riggins (prob. along rd. 517), 7/21/54.

Bingham 307 and Bingham and Miller 415 & 437, ID, east-southeast-facing slope in a moderately dense *Abies lasiocarpa, Pinus contorta* forest ca. ¼ mi northwest of Crater Lake below trail 101, 6,720', 7/9/81; north-facing, 2/3-shaded rocky hillside in an *Abies lasiocarpa, Picea engelmannii, Pinus contorta, Pseudotsuga menziesii* forest along trail 112 ca. ¼ mi westof its crossing of the west fork of the west fork of Sheep Cr., 6,800', 8/10/81; and east-facing, heavily shaded, rocky slope with a dense *Abies lasiocarpa, Picea engelmannii, Pinus contorta, Alnus sinuata* forest along trail 192 ca. 100' southwest of its jct. with trail 113 ca. 1/3 mi south of Rankin Mill, 6,240', 8/16/81; respectively.

Davis 6/28/40, IDF 83008, Papoose Cr. 8 mi southwest of Riggins (prob. along rd. 517), 6/28/40.

Plus 6 Sight Records by Bingham and Miller and C. Johnson, Caribou Cr. to Ruth Lake, 5,800-7,300'.

Pyrola minor L., Snowline Pryola.

Uncommon, central and southern Seven Devils and west fork Rapid River, 6,000-7,400'.

Bingham and Miller 352, ID, and 422, ID and WS, east-facing slope in a dense *Abies lasiocarpa, Picea engelmannii* forest in the bottom of the Mirror Lake fork of Bridge Cr. just above the bench swamp ca. ½ mi east of Mirror Lake, 7,300', 7/26/81; and benchland with an open forest of *Abies lasiocarpa, Picea engelmannii,* and *Pinus contorta,* moderately moist, 1/3-shaded, along trail 112 on the plateau at the very head of Bernard Cr. ca. ¼ mi southwest of the jct. of trails 112, 140, and 57 at the Iron Phone, 7,400', 8/10/81; respectively.

*Christ 8630, ?NY, springy places on mountainside, Black Lake, 8/8/37.

Plus 3 Bingham and Miller Sight Records, along east fork Sheep Cr. trail 58 ca. ½ mi north of trail 112, 6,000', 8/18/82; along rd. 106 ca. 1 mi north of Lockwood Saddle, 6,550', 6/30/82; and along the west fork Rapid River trail 113 ca. ¼ mi above Deep Cr., 4,200', 6/9/82.

?*Pyrola picta* Smith, White-vein Pyrola, (not known for north-central Idaho).

C. Johnson Sight Records: Plot 7022, east of trail 112 along the south fork of Little Granite Cr. ca. 2 mi south of Hibbs Cow Camp, 5,820', 8/11/83; and Plot 7043, west of trail 214 ca. 1¼ mi north of Emerald Lake, 6,440', 8/18/83.

Pyrola secunda L. var. *secunda*, Side-bells Pyrola.

Abundant, entire Seven Devils, 5,200-7,600'.

Baird 8/18/71, Council R.D., along rd. 105 ca. 2 mi south of Landore, 5,500', 8/18/71.

Baker 12260, ID, moist woods along Shingle Cr. (along rd. 517), 7/31/54.

Bingham and Miller 163, ID and WS, east-facing, moist streambottom with a dense *Abies lasiocarpa-Picea engelmannii* forest, in the bottom of Hanson Cr. just below the Old Boise Trail 101, 6,700', 7/17/80.

Plus 41 Sight Records by Bingham and Miller, C. Johnson, and Steele, Wild Horse Butte to just south of Emerald Lake, 5,250-7,600'.

Pyrola uniflora L. Single Delight.

Uncommon, central and southern Seven Devils, 6,500-7,200'.

Bingham and Miller 160, east-facing, very moist streambank in a dense *Abies lasiocarpa, Picea engelmannii* forest in the bottom of Hanson Cr. just below the Old Boise Trail 101, 6,700', 7/17/80.

Plus 6 Sight Records by Bingham and Miller, and C. Johnson, bottom Bernard Cr. along trail 57, bottom Dog Cr., McGaffee Cow Camp water hole, along trail 113 ca. ½ mi southwest of Rankin Mill, along trail 124 in the Echo Lake fork of Little Granite Cr., along rd. 112 just south of Rock Cr., 6,500-7,200'.

Vaccinium globulare Rydb., Globe Huckleberry.

Uncommon, central and southern Seven Devils, 5,100-7,300'.

*Nelson and Nelson 2973, ?RM, Dry Diggins Camp, 8/10-15/38.

Steele Sight Records: Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,100', 6/12/72; Stand 74-37, above Shingle Cr. on rd. 517, 6,960', 8/8/74; Stand 74-38, below the south fork of Papoose Cr. along rd. 517, 5,800', 8/8/74; and Stands 81-Pa-01A and 01B, along rd. 105 6 mi above Cuprum, 5,550', 6/24/81.

(Apparently there are taxonomic problems between *V. globulare*, generally to the south, and *V. membranaceum* to the north; perhaps the Seven Devils plants are intermediate.)

Vaccinium membranaceum Dougl., Thin-leaved Huckleberry.

Abundant, entire Seven Devils and Rapid River, 5,000-7,600' (see discussion under *V. globulare*, above).

Baker 12089, ID, steep rocky banks below Heavens Gate, 7/21/54.

Bingham and Miller 129, ID and WS, east-facing, almost completely shaded streambanks and bottom in a *Picea engelmannii, Abies lasiocarpa, Pseudotsuga menziesii* stand, just above the Old Boise Trail at Hanson Cr., 6,800', 7/16/80.

*Christ 8593 & 12695, ?NY, on timbered mountainside 6 mi north of Bear, 8/8/37; and timbered mountainside along Sheep Cr. trail (112), 7/17/41; respectively.

Plus 51 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle south to Lockwood Saddle, 5,000-7,600'.

Vaccinium ovalifolium Smith, Oval-leaf Huckleberry.

Scarce, central Seven Devils, 7,300' ±.

*Nelson and Nelson 2973, ?RM, Dry Diggins Camp, 3-4' high, berries blue, 8/10-15/38.

Vaccinium scoparium Leiberg, Grouse Whortleberry.

Abundant, central and southern Seven Devils, 6,200-8,400'.

Bingham and Miller 417, ID and WS, flat, half-open, deep loamy bench under a *Picea engelmannii, Pinus contorta, Abies lasiocarpa* stand, at the jct. of trails 140, 112, and 57 at the Iron Phone, 7,300', 8/10/81.

*Christ 8694 & 12680, ?NY, mats under *Abies lasiocarpa*, Black Lake, 8/8/37; and mostly under cover with *Pinus contorta*, Sheep Cr. (prob. along trail 112), 7/17/41; respectively.

Davis 2387, WS, Heavens Gate, 6/28/40.

*Nelson and Nelson 2972, ?RM, Dry Diggins Camp, 8/10-15/38.

Sharp and McKendrick 9/2/65, IDF 83014, moist woods, Heavens Gate Lookout, 9/2/65.

St. John and Mullen 8468, WS, edge of woods, Dry Diggins, 7/20/27.

Plus 52 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Fabaceae

Astragalus arthuri Jones, Arthur's Milk-vetch.

Scarce, lower Rapid River, 2,200' ±.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 ca. ¼ mi above the Circle C State Fish Hatchery trailhead gate, 2,250', 6/8/82.

Astragalus canadensis L. var. *mortonii* (Nutt.) Wats., the variety of Canadian Milk-vetch having both black and white calyx hairs.

Uncommon, entire lower Seven Devils, 5,000-6,800'.

Baker 11996, ID, dry bank of wooded slope along the Seven Devils rd. 5 mi west of Riggins (prob. in Papoose Cr. along rd. 517), ? elev., 9/3/53.

Bingham 551, ID, and Bingham and Miller 592, ID and WS, open, ridgetop grass-forb-sedge stand ca. 150' northeast of the Grave Point Lookout tower, 5,630', 7/21/82; and in a southeast-facing *Pinus contorta-Picea engelmannii-Abies* *lasiocarpa* stand along rd. 517 ca. ¼ mi below the north fork of Shingle Cr., 6,850', 8/17/82; respectively.

*Christ 8594, ?NY, timbered mountainside 6 mi north of Bear (prob. near the south end of rd. 112), 8/8/37.

Davis 2397, IDF, moist woods, Papoose Cr. 9 mi southwest of Riggins, (prob. along rd. 517 on McClinery Ridge), 6/28/40.

Plus 1 Sight Record by C. Johnson.

Astragalus canadensis L. var. undet., Canadian Milk-vetch.

2 Sight Records by Bingham and Steele.

***Astragalus cusickii* Gray var. *cusickii*, Cusick's Milk-vetch.

Rare, central Seven Devils, 5,000' ± (recommended for a "State Watch List" of plants rare in Idaho but not threatened unless major changes occur in local land use, cf. Steele and others 1981).

Meyer 1605, WS, bare, exposed south slope above the east side of Sheep Cr. 3 mi from the Snake River, ? elev., 5/11/39.

***Astragalus cusickii* Gray var. *flexilipes* Barneby, the 9 to 13 leafleted variety of Cusick's Milk-vetch.

Rare, central Seven Devils and Rapid River, 5,000' ± (recommended for a Federal Watch List" of plants rare in the U.S. and Idaho but not threatened unless major changes occur in local land use, cf. Steele and others 1981).

Baker 11997 & 12154, ID, dry banks of wooded slope along the Seven Devils rd. 5 mi west of Riggins (prob. along rd. 517 in Papoose Cr.), ? elev., 7/21/54; and White Bird Ridge (off the Little Salmon River), 7/27/54; respectively.

Bingham and Miller 480, ID and WS, open, southeast-facing, overgrazed and weedy hillside in the *Agropyron spicatum/Celtis reticulata* h.t. ca. 0.1 mi up the lower Rapid River trail 113 from the Circle C State Fish Hatchery trailhead gate, 2,250', 6/8/82.

Lathyrus nevadensis Wats. ssp. *cusickii* (Wats.) Hitchc., the subspecies of Nuttall's Pea having bristle-like tendrils and white flowers.

Scarce, southern Seven Devils, 6,000' ±.

Baird 6/12/72, Council R.D., along Indian Cr. 2 mi above Cuprum, 5,000', 6/12/72.

Lewis 1290, OGDF, and Lewis 2265, BOIS, OGDF, open coniferous timber near pass north of Horse Mt., 5,000', 6/16/67; and Steele Stand 72-Pa-24, along the Bear-Cuprum rd. 002 at the Bear-Indian Cr. divide, sec. 21, T. 20 N., R. 3 W., 5,790', 6/12/72.

R. and M. Spellenberg 1753, ID, WS, WTU, under ponderosa pine and Douglas-fir, 5 mi north of Cuprum on the Sheep Rock rd. (106), 6/16/67.

Lathyrus nevadensis Wats. ssp. *lanceolatus* (Howell) Hitchc. var. *parkeri* (St. John) Hitchc., the subspecies of Nuttall's Pea with typical tendrils and the variety with white flowers.

Scarce, northern and southern Seven Devils, 5,000-5,300'.

Bingham and Miller 503, ID and WS, east-facing, 3/4-open, gravelly rd. cut along rd. 672 ca. ¼ mi northward from China Cr. Saddle, 5,300', 6/10/82.

Plus Steele Sight Record, Stand 72-Pa-24, along the Bear-Cuprum rd. 002 above Huntley Gulch, 5,000', 6/12/72.

?*Lathyrus ochroleucus* Hook., Cream-flowered Pea.

*Christ 11062, ?NY, in yellow pine woods near Cuprum, 5/30/40 (but south of its usual north Idaho range, possibly *L. nevadensis*, see above).

Lathyrus pauciflorus Fern. ssp. *pauciflorus* var. *utahensis* (M. E. Jones) Peck, the long-flowered subspecies and broad-leaved variety of the Few-flowered Pea.

Occasional, lower southern Seven Devils, 5,000' ±.

Baird 6/12/72, Council R.D., along Indian Cr. 2 mi above Cuprum, 5,000', 6/12/72.

Lewis 2262, BOIS, OGDF, along rd. 105 6 mi north of Cuprum, 5,000', 6/12/72.

Steele 298, BOIS, Steele Stand 72-Pa-26, along rd. 002 at the Bear-Indian Crs. divide, 5,100', 6/12/72.

Plus Steele Sight Record, Stand 72-Pa-24, along the Bear-Cuprum rd. 002 above Huntley Gulch, 5,000', 6/12/72.

Lupinus argenteus Pursh, var. undet., Silvery Lupine.

Scarce, southern Seven Devils, 5,500-7,100'.

Holmgren and Tillett 9602, WS, Kinney Point, 7/14/53.

Steele Sight Record, Stand 81-Pa-01A, along the Indian Cr. rd. 105 ca. 6 mi above Cuprum, 5,550', 6/24/81.

Lupinus caudatus Kell., Kellogg Spurred Lupine.

Common, entire Seven Devils, 5,200-8,400'.

Baird 6/26/72, Council R.D., 2 mi above rd. 002 at Huntley Gulch, 5,000', 6/26/72.

Bingham and Miller 439, ID, open grass-forb meadow at Old Town (old mining camp at the jct. of trails 113 and 191 along the west fork of the Rapid River), ½ mi south of Rankin Mill, 6,160', 8/16/61.

C. Johnson 8/18/83 & 8/20/83, BKR 2487 and 2467, Plot 7040, along the Old Boise Trail 101 ca. 1/8 mi north of Horse Heaven Saddle at the jct. of trails 101, 114, and 124, 7,930', 8/18/83; and Plot 7053, along trail 192 southwest of its jct. with trail 113 northwest of Carbonate Hill, 7,620', 8/20/83; respectively.

Q. Jones 215, ID and WS, mountain meadow, Heavens Gate, 7/13/50.

Steele 50, BOIS, Stand 72-Pa-25, Bear-Indian Cr. divide, sec. 28, T. 20 N., R. 3 W., 5,130', 6/12/72.

Wellner 1685, ID, north of the Lookout on Pollock Mt., 8,050', 8/6/78.

Plus 29 Sight Records by C. Johnson and Steele.

Lupinus caudatus Kell. X ?*L. laxiflorus* Dougl., a possible natural hybrid between the Kellogg Spurred Lupine and the Spurred Lupine.

Scarce, central Seven Devils, 7,800' ±.

C. Johnson Sight Record, Plot 7046, south of trail 113 just south of its jct. with trail 192 ca. ¼ mi north-northwest of Carbonate Hill, 7,770', 8/20/83.

Lupinus laxiflorus Dougl. var. *calcaratus* (Kell.) C. P. Smith, the white-flowered variety of Spurred Lupine.

Occasional, northern and central Seven Devils, 6,400-8,000'.

Bingham and Miller 223B & 533A, ID and WS, on moist talus below the rimrock at the upper, west edge of the Horse Heaven Lookout pasture ca. ¼ mi southwest of the lookout cabin, 8,000', 8/25/80 (growing with *L. laxiflorus* v. *laxiflorus*, Bingham and Miller 223A, below); and in an open, southwest-facing, *Pseudotsuga menziesii* forest along rd. 1819 ca. 0.9 mi southwestward from its jct. with rd. 420 at Buckhorn Spring, 6,420', 7/21/82 (growing with *L. laxiflorus* v. *pseudoparviflorus*, Bingham 533B, below); respectively.

*Christ 12521, ?NY, open, grassy east slopes, Heavens Gate, 7/12/41.

*Nelson and Nelson 2983, ?RM, Horse Heaven, 8/10-15/38 (bicolored white and blue spike).

Lupinus laxiflorus Dougl. var. *laxiflorus*, Spurred Lupine.

Abundant, entire Seven Devils and west fork Rapid River, 5,000-8,400'.

Aldrich 7/04/07, ID 3106, Camp Howard (prob. the Cow Camp), 5,000', 7/04/07.

Baker 12008, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 223A, ID and WS, in moist talus below the rimrock at the upper west edge of the Horse Heaven Lookout pasture ca. ¼ mi southwest of the lookout cabin (growing with Bingham and Miller 223B *L. laxiflorus* v. *calcaratus*, above), 8,000', 8/25/80.

Davis 2529, WS, Smith Mt. Lookout, 7/3/40.

Hermann 12034, WS, ?NA, and 12045, WS, ?NA, ?US, vicinity of Cold Springs Lookout, 6,900', 8/6/55; and 11.5 mi southwest of Riggins above Shingle Cr. (prob. along rd. 517), 8/6/55; respectively.

Kruckeberg 3186, WS, WTU, clearings and swales on north-facing wooded slopes at saddle at end of Seven Devils rd. (Wind Saddle at the, then, end of rd. 517) 18 mi west of Riggins, 7,500', 7/30/52.

Tisdale 7/16/79, IDF 81143, northwest slope of Bald Mt., near plot 93 2 mi north of Heavens Gate Lookout, 7,600-7,800', 7/16/79.

Plus 34 Sight Records by Bingham and Miller.

Lupinus laxiflorus Dougl. var. *pseudoparviflorus* (Rydb.) Smith and St. John, the lower elevation variety of Spurred Lupine, with glabrous upperleaves and smaller-blue-flowers.

Uncommon, entire Seven Devils, 5,700-8,000'.

Baker 11311, ID, Sheep Rock, Hells Canyon, 9/3/53.

Bingham 533B, ID and WS, open, southwest-facing Douglas-fir forest along rd. 1819 ca. 0.9 mi southwestward from Buckhorn Spring at the jct. of rds. 1819 and 420, 6,420', 7/21/82 (growing with *L. laxiflorus* v. *calcaratus*, Bingham 533A, above).

*Christ 8644, 12533, & 12548, ?NY, in timber surrounding Black Lake, 8/8/37; open east slopes, Heavens Gate, elev. ca. 8,000', 7/12/41; and rocky crest of divide, Heavens Gate, 7/12/41; respectively.

*Hermann 12051, ?NA, 1 mi below Shingle Cr. (prob. along rd. 517), 6,000', 8/7/55.

Packard 436 & 560, WS, trail from Hibbs Cow Camp to "the Swamps" (prob. the abandoned cutoff trail that crosses the "swamps" and joins trail 112 northeast of Hibbs Cow Camp), 7,900' (prob. nearer 7,300'), 7/27/38; and wooded slope on ridge northeast of Sheep Cr. 2,500' above the rim (prob. rim of Snake River Canyon), 5/12/39; respectively.

St. John and Mullen 8433, WS, McGaffee Cow Camp, 7/19/27.

Lupinus leucophyllus Dougl. var. undet., Velvet Lupine.

Common, entire Seven Devils, 5,200-7,900'.

Baker 11995 & 12153, ID, dry banks, wooded slope 5 mi west of Riggins (prob. along rd. 517 in Papoose Cr.), ? elev., 7/21/54; and dry hillsides, White Bird Ridge (off Little Salmon River), ?elev., 7/27/54; respectively.

Bingham and Miller 119, ID and WS, along the Cannon-Hanson Crs. ridge ca. ½ mi west of the Old Boise Trail 101, 7,600', 7/15/80.

Brewer 78, Council R.D., Smith Mt., sec. 25, T. 21 N., R. 2 W., 7,800', 8/17/29.

Plus 17 Sight Records by Bingham and Miller, Sawpit Saddle to head of Deep Cr., 5,050-7,900'.

Lupinus sericeus Pursh var. *sericeus*, Silky Lupine.

Uncommon, entire Seven Devils, 5,600-7,800'.

Baker 12057 & 12087, ID, steep rocky bank below Heavens Gate, 7/21/54; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Baird 9/8/71, Council R.D., open area at Towsley Spring, 7,000', 9/8/71.

Bingham 550, ID and WS, open grass-forb stand on rocky ridgetop, Grave Point Lookout, 5,630', 7/21/82.

M. E. Jones 26583, ? Herb., Seven Devils Mts., Washington Co., Idaho, 6,000', 8/5/1899 (cf. Hitchcock and others, Part 3, page 277, 1961 and Smith, 1951, page 691. There was no Adams Co. in 1899, only Washington and Idaho Counties).

Plus 5 Sight Records by C. Johnson, southeast of Haas Lake along the Old Boise Trail 101 to the head of Deep Cr. off rd. 112, 6,900-7,350'.

Lupinus sericeus Pursh var. undet., Silky Lupine.

*Christ 8612 & 12525, ?NY, gravelly mountainside, Smith Mt. rd., 8/8/37; and open east slope, Heavens Gate, 7,500', 7/12/41; respectively.

LaZelle 11, ID, ¼ mi east of Seven Devils Campground, 8/29/63.

*Packard 268, ?WS, open flat on Timbered Bench, 6,000', 6/20/37.

*St. John and Mullen 8605, ?WS, Sheep Cr. (along trail 110), 7/26/27.

Plus 4 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Medicago lupulina L., Hop Clover (European introduction).

Scarce (mostly from lower elevs.), central Seven Devils, 5,000' ±.

Bingham and Miller 583, ID, in the roadbed of rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Medicago sativa L., Alfalfa (escaped European agricultural plant).

Scarce, Rapid River only, 2,200-3,300'.

Bingham and Miller Sight Records: along the lower Rapid River trail 113 ca. ¼ mi above the Circle C State Fish Hatchery trailhead gate, 2,300', 6/8/82; and along the west fork Rapid River trail 113 ca. 1½ mi above the main River forks in sec. 26, 3,300', 6/9/82.

Melilotus alba Desr., White Sweet-clover (Eurasian introduction).

Scarce (mostly at low elevs.), Rapid River only, 2,200' ±.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 just above the Circle C State Fish Hatchery trailhead gate, 2,200', 6/8/82.

Thermopsis montana Nutt. var. *ovata* (Robins.) St. John, the Rocky Mountain variety of Golden Pea.

Frequent, northern and southern Seven Devils, 5,000-6,500'.

Bingham and Miller Sight Records: vicinities of Buckhorn Spring, 6,450'; Cow Cr. Saddle, 5,300'; Big Canyon Saddle, 4,800'; Low Saddle, 6,100'; Sawpit Saddle, 5,200'; and rd. 672 north of Cow Cr. Saddle, 5,200'.

C. Johnson Sight Records: Plot 784, along rd. 2060 ¼ mi east of Kirkwood Cr., 5,220'; and Plot 790, along rd. 2060 just eas of Kirkwood Cr., 5,300'.

*Hermann 12042, ?NA, ?US, edges of Douglas-fir woods on rd. near Cold Springs Lookout (rd. 1819), 6,800', 8/6/55.

Packard 581, WS, partly shaded dray 3½ mi up the Clark's fork of Sheep Cr. near Stormy Point, 5/13/37.

Steele Sight Records: 2 stands (81-Pa-01A and B) along the Indian Cr. rd. 6 mi above Cuprum, 5,550'.

Trifolium eriocephalum Nutt. var. *piperi* Martin, the round-leaved variety of Woolly-head Clover.

Occasional, central Seven Devils, 7,200-7,300' ±.

Christ 12727, ID, edges of marsh, Sheep Cr. Swamp, 7/17/41.

Ownbey and Meyer 2094, WS, dry, gravelly meadow, Hibbs Cow Camp, 6/26/40.

Packard 318, WS, swampy, alpine meadow near "The Swamps", near Lily Pad Lake, 6/28/37.

St. John and Mullen 8494, WS, moist meadow, Dry Diggins, 7,200', 7/20/27.

Trifolium latifolium (Hook.) Greene, Twin Clover.

Uncommon, northern and central Seven Devils, 5,000-6,800'.

Aldrich 7/04/07, ID 3214, Camp Howard (prob. the Cow Camp), 5,000', 7/04/07.

Baker 12001, ID, moist grassy bank, wooded slope, 9 mi west of Riggins (along rd. 517 on McClinery Ridge), 7/21/54.

*Hermann 12041, ?NA, ?US, white fir slope near Cold Springs Lookout, 6,800', 8/6/55.

Packard 224, WS, under open pine stand, Timbered Bench above Little Granite Cr., 5/15/37.

Peters 133, WS, moist sandy soil under conifers near McGaffee Cow Camp on the summit of the Bernard-Sheep Crs. ridge, 5,000', 5/16/36.

Plus 1 Steele Sight Record, Stand 74-38, below the south fork of Papoose Cr. on rd. 517, 5,800', 8/8/74.

Trifolium longipes Nutt. var. *reflexum* Nels., the white- and reflexed-flowered variety of Long-stalked Clover.

Common, entire Seven Devils, 5,500-8,000'.

Bingham 277, ID and WS, northeast-facing, moderately moist, hal shaded, rocky hillside in a *Pseudotsuga menziesii* stand, along rd. 2060 ca. 0.8 mi northwards from Meyer Cr., 5,48 7/8/81.

Henderson 3852, ID, along the Sheep Cr. Lakes trail 123 between Sheep and Shelf Lakes, 7/5/77.

Plus 23 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to Black Lake, 5,000-8,000'.

Trifolium macrocephalum (Pursh) Poiret, Big-head Clover.

Scarce, northern Seven Devils, 5,200' ±.

Lewis 2269, BOIS, OGDF, near Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72.

C. Johnson Sight Record, Plot 789, along rd. 2060 ¼ mi east of Kirkwood Cr., 5,220', 6/29/82.

Trifolium pratense L., Cultivated Red Clover (European introduction).

Occasional, central Seven Devils, 5,900-7,300'.

Bingham and Miller 599, ID and WS, north-facing, half-open, rocky hillside in an *Abies grandis-Pseudotsuga menziesii* forest of the *Abies grandis/Pachistima myrsinites* h.t. along trail 58 ca. 1¼ mi north of trail 112, 5,900', 8/18/82.

Bingham and Miller Sight Records: along the Old Boise Trail ca. ½ mi north of Hanson Cr., 6,800', 7/27/81; and along trail 112 ca. ¼ mi southwest of its jct. with trails 140 and 57, 7,300', 8/10/81.

Trifolium repens L., White Clover (European introduction).

Uncommon, northern and central Seven Devils and Rapid River, 5,000-7,300'.

Bingham and Miller 574, ID and WS, gently west-facing open, gravelly roadbed along rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Bingham and Miller Sight Records: along trail 104 ca. 0.1 mi east of Big Canyon Saddle, 4,900', 6/11/82; along trail 140 ca. 1 mi north of trail 112, 7,300', 8/12/81; along the east fork Sheep Cr. trail 58 ca. 1¼ mi north of trail 112, 5,900', 8/18/82; at the Circle C State Fish Hatchery trail 113 gate, 2,200', 6/8/82; along trail 192 ca. 3/4 mi east of the jct. of trails 189 and 192, 6,600', 8/16/81; along trail 124 between the Echo Lake fork and the south fork of Little Granite Cr., 6,700', 8/14/81; and along the west fork Rapid River trail 113 ca. ¼ mi east of Cottonwood Cr., 3,500', 6/8/82.

Vicia americana Muhl. var. *truncata* (Nutt.) Brew., the glabrous variety of American Vetch.

Occasional, entire Seven Devils, 5,000-6,200'.

Bingham and Miller 440, ID, east-facing, gently sloping, moderately moist grass-forb meadow bordering an *Abies lasiocarpa, Picea engelmannii, Pinus contorta* forest at Old Town at the jct. of trails 113 and 191, 6,160', 8/16/81.

Bingham and Miller Sight Record, along rd. 672 ca. 3/4 mi northeast of Cow Cr. Saddle, 5,200', 6/10/82.

Lewis 2276, BOIS, OGDF, Steele Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72.

Steele 113, BOIS, Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,100', 6/12/72.

nariaceae

Dicentra cucullaria (L.) Bernh.

Scarce, southern Seven Devils, 5,000' ±.

Lewis 1288, OGDF, open, bare slope, pass just north of Horse Mt., 5,000', 6/16/67.

tianaceae

Frasera albicaulis Dougl. var. *albicaulis*, the pubescent variety of the White-stemmed Frasera.

Uncommon, northern Seven Devils and Rapid River, 5,000-6,800'.

Bingham 303, ID and WS, southwest-facing, open, rocky hillside grassland along rd. 1819 ca. 1/3 mi east of Cold Springs Cow Camp, 6,800', 7/10/81.

Plus 6 Sight Records by Bingham and Miller, C. Johnson, and

Tisdale, Big Canyon Saddle and Motthorn Saddle to Caribou Cr. and Cold Springs Cow Camp, 5,000-6,700'; also Rapid River.

Frasera albicaulis Dougl. var. *cusickii* (Gray) Hitchc., the glabrous and more or less petaloid crown-scaled Cusick's Frasera.

Scarce, southern Seven Devils, 5,000' ±.

*Christ 11073, ?NY, mountainside in Snake River Gorge west of Cuprum, 5/30/40.

***Frasera albicaulis* Dougl. var. *idahoensis* (St. John) Hitchc., the glabrous and lacerate crown-scaled variety of the White-stemmed Frasera.

Rare, southern Seven Devils, 5,000-6,600' (recommended for a "Federa Watch List" of plants rare in the U.S. and Idaho, but not threatened unless marked changes in local land use occur [cf. Steele and others 1981]).

Baird 6/26/71, Council R.D., 1 mi above rd. 002 on Huntley Gulch, 5,000', 6/26/71.

Bingham and Miller 606 & 613, ID and WS, open, south-facing, subalpine grassland along the west or uphill side of the Horse Mt. rd. 108 ca. 0.5 mi south of Lockwood Saddle, 6,600', 7/27/83; and open, southeast-facing grass-forb sta on a rocky hillside west of and above the Black Lake rd. 112 ca. 1½ mi northwards from its jct. with rd. 105, 5,850', 7/28/83 (an almost white form); respectively.

Cusick 2226, WS, dry, stony hills near Cuprum, ? elev., 7/10/99? (an isotype specimen recognized by the author at WS).

Lewis 2277, BOIS, OGDF, near Steele stand 72-Pa-26 along the Cuprum rd. 105, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72 (apparently another white variant, since initially identified as *Frasera montana* Mulford).

Steele 896, BOIS, basalt scabland, Cuprum-Fruitvale rd. 127, sec. 11, T. 19 N., R. 2 W., 5,750', 6/27/74.

Steele Sight Record, Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,130', 6/12/72 (also originally identified as *F. montana*).

?*Frasera montana* Mulford, White Frasera.

*Christ 8605, ?NY, high, open mountainside, Smith Mt., 8/8/37 (this is the only Seven Devils collection of this taxon; it's suspect because of the three collections of a white variant of *F. albicaulis* var. *idahoensis*, from the same general locality, as noted above).

Frasera speciosa Dougl., Giant Frasera.

Scarce (mostly at lower elevs.), central Seven Devils, 7,000' minus

St. John and Mullen 8594, rocky ridge on Sheep Cr., 7,000' (prob. along trail 110 on or near the Snake-Salmon Rivers divide), 7/26/27.

Gentiana calycosa Griseb. var. *obtusiloba* (Rydb.) Hitchc., the large calyx-lobed variety of the Mountain Bog Gentian.

Frequent, central and southern Seven Devils, 6,900-8,300'.

Bingham and Miller 31, 77, & 234, ID, boggy flat at the head o the pond at the northeast side of Sheep Lake near the foo of the Goat Pass manway, 7,885', 7/22/79; open, subalpine sedge-forb meadow in the valley ca. ½ mi directly north o the summit of He Devil Mt., 8,300', 7/25/79; and in small shady bog along the Ruth Lake trail ca. 0.1 mi east of th Lake, 7,200', 8/27/80; respectively.

*Christ 8652 & 12636, ?NY, in timber in cirque on Pyramid Peak, 8/8/37; and marshy banks of Baldy Lake, 7/15/41; respectively.

*St. John and Mullen 8573, ?WS, creek bank, Little Granite Cr. (prob. in the head of the Echo Lake fork), 8,500', 7/24/27.

Taylor 1668 & 1669, WWB, Shelf Lake area, 7,440' +, 9/17/67; and near Sheep Lake, 7,875' +, 9/17/67; respectively.

Plus 9 Sight Records by Bingham and Miller, Bernard Lakes to S Lake Basin, 6,950-8,000'.

Geraniaceae

Erodium cicutarium (L.) L'Her., Crane's Bill (European introduction).

Occasional (mostly at lower elevs.), entire Seven Devils and Rapid River, 5,000-5,300'.

Bingham and Miller Sight Records: along rd. 420 ca. ½ mi south of Cow Cr. Saddle, 5,250', 6/10/82; at the lower Rapid River trail 113 trailhead gate at the upper end of the Circle C State Fish Hatchery, 2,200', 6/8/82; and along the west fork Rapid River trail 113 in the McCrea Place pasture, 4,000', 6/9/82.

Geranium pusillum Burnm., Small-flowered Cranesbill (European introduction).

Scarce (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000' ±.

Bingham 298, ID, on an open, rocky ridge in a *Festuca idahoensis/Koeleria cristata* h.t. at Sawpit Saddle, 5,050', 7/8/81.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 near Blue Gulch, 2,600', 6/8/82.

Geranium viscosissimum Fisch. and Mey. var. *nervosum* (Rydb.) Hitchc., the glabrous-stemmed variety of the Western Geranium.

Scarce, southern Seven Devils, 5,800' ±.

Bingham and Miller 518, ID and WS, grass-forb-sedge meadow in an open *Pinus ponderosa, Pseudotsuga menziesii, Abies grandis, Larix occidentalis* forest along Black Lake rd. 112 ca. 1½ mi south of Placer Basin, 5,850', 6/30/82.

Geranium viscosissimum Fisch. and Mey. var. *viscosissimum*, Sticky Purple Geranium.

Scarce (mostly at lower elevs.), northern Seven Devils, 5,000-5,300'.

Bingham 531, ID and WS, shrubby opening in a *Pseudotsuga menziesii-Physocarpus malvaceus* on a southeast-facing slope, along rd. 672 ca. ½ mi south of China Saddle, 5,300', 7/21/82.

Bingham and Miller Sight Record, along rd. 420 ca. ½ mi south of Cow Cr. Saddle, 5,300', 6/10/82.

Grossulariaceae

Ribes cereum Dougl. var. *cereum*, Squaw Currant.

Scarce, Rapid River only, 2,800' ±.

Bingham and Miller Sight Record, along the west fork Rapid River trail 113 ca. ¼ mi west of the main forks in sec. 26, 2,800', 6/8/82.

Ribes cereum Dougl. var. *colubrinum* Hitchc., Snake River Squaw Currant.

Occasional, northern and central Seven Devils, 5,000-6,000'.

Bingham and Miller 566, ID and WS, in a *Pseudotsuga menziesii-Pinus ponderosa* stand in a small saddle along rd. 517 ca. 0.3 mi up the rd. from its 2d crossing of Papoose Cr. in sec. 26, 4,700', 8/17/82.

Comstock 109, WS, near ridge between Sheep and Lightning Crs., 6,000', 5/12/39.

C. Johnson 5/25/82, BKR 2207, Plot 720, above trail 104 ca. ½ mi northwest of Motthorn Saddle, 5,100', 5/25/82.

Packard 5/36, WS 107861, high rocky slope near head of north fork Bernard Cr., McGaffee Cow Camp, 5/36.

Ribes cereum Dougl. var. *inebrians* (Lindl.) Hitchc., the variety of Squaw Currant having acute floral bracts and pubescent-glandular calyces.

Uncommon, central Seven Devils, 7,200-8,400'.

Baker 12040, ID, open alpine slope, Seven Devils Camp, 7/21/54.

Bingham and Miller 106 & 242, ID and WS, and 426, ID, open, south-facing, steep slope with a deep, moderately moist soil and an open *Pinus contorta* forest ca. 0.1 mi north of Seven Devils Guard Station, 7,250', 7/14/80; southwest-facing, 3/4-open, rocky slope with a grass-forb stand under scattered *Pseudotsuga menziesii* trees, ca. 0.1 mi northwest of Stevens Saddle along trail 192, 7,600', 8/27/80; and open, bedrock ridgetop with a scattered, sub-alpine forb stand mostly in rock crevices, ca. 50' south of Dry Diggins Lookout, 7,825', 8/11/81; respectively.

Q. Jones 224, ID and WS, Heavens Gate Lookout, 8/13/50.

Ribes cereum Dougl. var. undet. (but not var. *cereum*), Squaw Currant.

Brewer 33, Council R.D., Patrolman Cr. (small creek north of Jackley Mt.) sec. 1, T. 22 N., R. 3 (prob. 3) W., 6,000', 8/30/28.

Plus 11 Sight Records by Bingham and Miller, C. Johnson, and Steele, from Camp Howard Triangulation Station south to the Bear-Indian Crs. divide, 5,100-7,500'.

Ribes hudsonianum Richards. var. *petiolare* (Dougl.) Jancz., the glabrous variety of Stinking Currant.

Frequent, entire Seven Devils and west fork Rapid River, 5,000-7,200'.

Bingham and Miller 248, ID and WS, in the bottom of the northernmost Ruth Cr. along trail 189, the first trail north of the Ruth Cr. trail, 6,800', 8/27/80 (heavily infected with *Cronartium ribicola* J. C. Fisch. ex. Rabenh.).

Packard 297, WS, near the head of the north fork of Little Granite Cr. below Hibbs Cow Camp, 7,000', 6/26/37.

Plus 12 Sight Records by Bingham and Miller, Meyer Cr. along rd. 2060 to 2 mi north of Lockwood Saddle along rd. 106, plus McCrea Place and Rankin Mill along the west fork Rapid River, 5,750-7,200'.

Ribes lacustre (Pers.) Poir., Prickly Currant.

Abundant, entire Seven Devils and Rapid River, 5,000-7,800'.

Bingham and Miller 110, ID and WS, east-facing, dry, rocky streambottom ca. 0.1 mi northwest of the Seven Devils Guard Station at the head of the north fork of Bridge Cr., 7,250', 7/14/80.

*Christ 8628, 8690, & 12687, ?NY, springy places on mountainside, Black Lake, 8/8/37; under cliffs on high ridges near Black Lake, 8/8/37; and at trail crossing (trail 112) in the bottom of Sheep Cr. (prob. the west fork) 7/17/41; respectively.

Christ 12608, ID, rocky promontory in Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41.

C. Johnson 6/29/82, BKR 2218, Plot 790, above rd. 2060 ca. 1/20 mi east of Kirkwood Cr., 5,300', 6/29/82.

*Nelson and Nelson 2974, ?RM, Dry Diggins Camp, 8/10-15/38.

Plus 40 Sight Records by Bingham and Miller, and C. Johnson, Wild Horse Butte and Big Canyon Saddle to Lockwood Saddle, 5,000-7,300'.

Ribes montigenum McClatchie, Alpine Prickly Currant.

Common, central and southern Seven Devils, 7,000-9,300'.

Baker 12291, ID, rocky mountain slope west of Seven Devils Camp, 7/31/54.

Bingham and Miller 17 & 100, ID, and 219, ID and WS, west-facing slope in an opening in a *Abies lasiocarpa-Pinus albicaulis* forest, protected by boulders, 40% shaded, ca. 300' west of the Snake-Salmon Rivers divide and 0.1 mi southwest of Heavens Gate Lookout, 8,350', 7/21/79; bedrock crevices in the 1st small saddle south of the summit of He Devil Mt., 9,300', 7/26/79; and cliff crevices along the west side of the Horse Heaven Lookout pasture ca. ¼ mi southwest of the Lookout cabin, 8,000', 8/25/80; respectively.

Christ 12481, ID and WS, slopes, ridges, and crags, Seven Devils Ridge, 7/11/41.

C. Johnson 8/20/83, BKR 2471, Plot 7046, south of the jct. of trails 113 and 192 ca. ¼ mi north of Carbonate Hill, *Pinus albicaulis/Polemonium pulcherrimum* community, 7,770', 8/20/83.

*Nelson and Nelson 3009, ?RM, top of He Devil, 8/10-15/38.

St. John and Mullen 8474 & 8496, WS, gravel ridge, head of Bernard Cr., Dry Diggins, 7,000', 7/20/27; and rocky crest of ridge, Dry Diggins, 7,500', 7/20/27; respectively.

Taylor 1670, WWB, talus slope above Gem Lake, 7,760' +, 9/17/67.

Plus 20 Sight Records by Bingham and Miller, C. Johnson, and Wellner (including Pollock Mt.).

Ribes niveum Lindl., Snow Gooseberry.

Uncommon (mostly at lower elevs.), northern and central Seven Devils and Rapid River, 5,000-6,200'.

Bingham and Miller Sight Records, Big Canyon Saddle to Rankin Mill, 5,000-6,200'; and lower and west fork of Rapid River, 2,200-3,600'.

Ribes setosum Lindl., Missouri Gooseberry.

Scarce, vicinity Motthorn Saddle in northern Seven Devils, 5,100' ±.

C. Johnson 5/25/82, BKR 2206, Plot 720, above trail 104 ca. ½ mi northwest of Motthorn Saddle, 5,100', 5/25/82.

Ribes velutinum Greene var. *gooddingii* (Peck) Hitchc., Goodding's Gooseberry.

Occasional, northern Seven Devils and Rapid River, 5,000' minus.

Bingham 471, ID and WS, northeast-facing, open clearcut in a *Pinus ponderosa, Pseudotsuga menziesii, Abies grandis* stand in the 1st saddle southeast of Motthorn Saddle ca. 3/4 mi north-northwest of Pittsburg Saddle, 4,500', 5/25/82 (located very close to BKR 2206, *R. setosum*, above, but keys to *R. velutinum* v. *gooddingii*).

Bingham and Miller Sight Records, along the lower Rapid River trail 113 ca. 1.0 mi above Blue Gulch, 2,500', 6/8/82; and along the west fork Rapid River trail 113 just west of the main forks in sec. 26, 2,800', 6/8/82.

Ribes viscosissimum Pursh var. *viscosissimum*, Sticky Currant.

Abundant, entire Seven Devils and west fork Rapid River, 5,000-7,600'.

Bingham and Miller 190, ID and WS, northeast-facing ½-shaded, rocky slope in an open *Pseudotsuga menziesii* forest bordering a snowslide area, ca. 1/2-3/4 mi north of Hanson Cr. along the Old Boise Trail 101, 6,800', 7/18/80.

*Christ 8596 & 12690, ?NY, timbered mountainside 6 mi north of Bear, 8/8/37; and open mountainside along Sheep Cr. trail (112), 7/17/41.

Comstock 107, WS, near peak of ridge between Sheep and Lightning Crs., 6,000', 5/12/39.

St. John and Mullen 8391, WS, Bernard-Sheep Cr. divide, McGaffee Cow Camp, 5,400', 7/17/27.

Plus 36 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle south to Landore, 5,000-7,600'.

***Ribes wolfii* Rothrock, Rothrock's Currant.

Rare, northern Seven Devils, 5,400-6,650' (recommended for a "State Watch List" of plants rare in Idaho but not threatened without major changes in present land use, cf. Steele and others 1981). Aside from the two collections of Bingham and Miller and St. John and Mullen, below, this normally southwestern (Utah, Colo., Ariz., N.Mex.) species is known from this region only from the vicinity of the Wenatchee Guard Station, Umatilla National Forest, southwest of Asotin, Wash. (cf. Hitchcock and Muhlick 21817, WTU), from Enos Lake in Valley Co., Idaho (cf. B. Ertter 477-3, CIT); and from along the Imnaha to Hat Point Road in Wallowa Co., Oreg. (cf. Rogers and Guilkey 6/40, OSC 69972).

Bingham 306, ID, IDF, and WS, along both sides of rd. 1819 from just west of Cold Springs Cow Camp to about 1 mi eastward, mostly open, southwest-northwest-facing rocky hillsides in a scattered *Abies lasiocarpa-Pinus contorta* forest, soil prob. of basaltic origin, 6,650', 8/12/81. (The population is a large one, possibly 500-1,000 plus plants. It does not seem to be suffering from domestic grazing; it's on a sheep driveway of 50 years or more use.)

St. John and Mullen 8390, WS, McGaffee Cow Camp in the head of the north fork of Bernard Cr., 5,400', 7/17/27. (This population, or another nearby, along trail 140 ca. 1/3 mi south of the jct. of trails 140 and 110 along the Bernard-Sheep Crs. divide, 6,650', composed of several plants, was seen 8/12/81 by Bingham and Miller. The elev. and date of of St. John's collection, however, indicates it is further down the ridge).

Hydrangeaceae

Philadelphus lewisii Pursh, Mock Orange.

Occasional (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000-5,300'.

Bingham and Miller Sight Records: along the lower Rapid River trail 113 at the Circle C State Fish Hatchery, 2,200', 6/8/82; along rd. 2060 ca. ½ mi south of Sawpit Saddle, 5,300', 7/8/81; along rd. 672 ca. 1/3 mi north of Cow Cr. Saddle, 5,200'; and along the west fork Rapid River trail 1 just north of the main forks in sec. 26, 2,800', 6/9/82.

Hydrophyllaceae

Hesperochiron pumilus (Griseb.) Porter, Dwarf Hesperochiron.

Scarce, northern Seven Devils, 5,200' ±.

Bingham and Miller 502, ID and WS, open grass-sagebrush slope near basalt rock ridgetop, along rd., 420 ca. 0.1 mi south of Cow Cr. Saddle, 5,240', 6/10/82.

Hydrophyllum capitatum Dougl. var. *capitatum*, Waterleaf.

Frequent, entire Seven Devils, 5,000-7,800'.

Bingham and Miller 130, ID and WS, southeast-facing, open to partly shaded rocky slope in open Engelmann spruce-subalpine fir forest, ca. ¼ mi down the Dog Lake manway from the Lake, 7,800', 7/16/80.

Brewer 8, Council R.D., Sheep Rock (actually Sheep Peak or Mt.) on Big (?Barber) Flat, 4,000' (but the Peak is 5,257'), 5/9

Moore 78, WS, Bernard Cr. trail (110), 3 mi from Snake River, 6,000', 5/16/36.

Ownbey and Meyer 2072, WS, dry rock slopes in open *Pseudotsuga Menziesii* forest, headwaters Sheep Cr., 6/26/40.

Packard 288, WS, open, yellow pine stand, Little Granite Cr. across from Willow Hill, 5,900', 6/26/37.

Plus 12 Sight Records by Bingham and Miller, C. Johnson and Steele, Big Canyon Saddle to Landore, 5,100-7,700'.

Hydrophyllum fendleri (Gray) Heller var. *fendleri*, Fendler's Waterleaf.

Scarce, Rapid River only, 2,400-3,200'.

Bingham and Miller 489, ID and WS, northwest-facing, 3/4-shaded, stabilized talus slope in an open, riparian Douglas-fir-*Ace glabrum-Betula occidentalis* forest, along the lower Rapid River trail 113 ca. 0.1 mi above Blue Gulch, 2,400', 6/8/82.

Plus 1 Sight Record by Bingham and Miller, along the west fork Rapid River trail 113 ca. 1 mi west of the main forks (in sec. 26), 3,200', 6/9/82.

Nemophila kirtleyi Hend., Snake River Canyon Nemophila.

Occasional, northern Seven Devils and Rapid River, 5,000' minus.

Bingham and Miller 474, ID, west-facing, ½-open, trailside cutbanks in a moderately dense bottomland conifer forest of the *Pseudotsuga menziesii/Physocarpus malvaceus*, along the lower Rapid River trail 113 opposite the mouth of Blue Gulch, 2,400', 6/8/82.

Bingham and Miller Sight Records: along the stock-drive portion of trail 104 ca. ½ mi east of Big Canyon Saddle, 4,600', 6/11/82; along the Old Boise Trail 101 ca. ½ mi south of its jct. with rd. 1819 southeast of Cold Springs Lookout, 6,800', 7/9/81; and along the west fork of the Rapid River trail 113 ca. 0.2 mi down the trail from its jct. with trail 62, 4,680', 6/9/82.

Nemophila parviflora Dougl. var. *austiniae* (Eastw.) Brand, the variety of the Small-flowered Nemophila having shallowly cleft leaves.

Occasional, central and southern Seven Devils, 5,000-6,800'.

Bingham and Miller 188, ID, east-facing, 2/3-shaded, moderately dry and under a brush canopy in an open *Pseudotsuga menziesii* forest along the Old Boise Trail 101 ca.

1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

Steele Sight Records: Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,130', 6/12/72; and Stand 72-Pa-26, same locality as above, 5,100', 6/12/72.

Phacelia hastata Dougl. var. *alpina* (Rydb.) Cronq., the lavender-flowered, subalpine variety of the Silverleaf Phacelia.

Uncommon, central Seven Devils, 7,200-8,800'.

Bingham and Miller 51 & 412, ID, west-facing, open, loose and large talus rock (4"-12"), ca. ¼ mi southeast of Sheep Lake on the long talus slope leading to the Tower-of-Babel - She Devil Mt. saddle, 8,500', 7/23/79; and west-facing, open, rocky slope in an open *Abies lasiocarpa-Pinus albicaulis* forest, along trail 112 ca. ¼ mi westward from the summit between the forks of Sheep Cr., 7,800', 8/10/81; respectively.

*Nelson and Nelson 2991, ?RM, Horse Heaven, 8/10-15/38.

St. John and Mullen 8540, WS, rockslides on He Devil Mt., 8,800', 7/24/27.

Plus 5 Sight Records by Bingham and Miller, Echo Lakes trail 129 to Stevens Saddle, 7,200-7,600'.

Phacelia hastata Dougl. var. intermediate between *alpina* (Rydb.) Cronq. and *leptosepala* (Rydb.) Cronq. (a white-flowered variety).

Scarce, central Seven Devils, 6,500-7,700'.

C. Johnson Sight Records: Plot 7048, above trail 113 ca. ¼ mi north of trail 192 and ca. 1/3 mi southwest of Rankin Mill, 6,500', 8/20/83; and Plot 7052, east of Trail 192 ca. 0.1 mi north of Stevens Saddle, 7,710', 8/20/83.

Phacelia hastata Dougl. var. *leptosepala* (Rydb.) Cronq., the white-flowered and tall variety of the Silverleaf Phacelia.

Scarce, central Seven Devils, 7,300-7,700' ±.

*Nelson and Nelson 3020, ?RM, Dry Diggins, 8/10-15/38.

C. Johnson Sight Record, Plot 7014, east of trail 124 ca. ¼ mi south of Potato Hill, 7,750', 8/10/83.

Phacelia hastata Dougl. var. undet., Silverleaf Phacelia.

C. Johnson Sight Record, Plot 7015, above trail 124 ca. 0.1 mi west of Potato Hill, 7,730', 8/10/83.

Phacelia heterophylla Pursh var. *heterophylla*, Varileaf Phacelia.

Common, entire Seven Devils, 5,200-8,100'.

Baker 12071, ID, dry, rocky banks above Seven Devils Guard Station, 7/21/54.

Bingham and Miller 177, ID and WS, southeast-facing, open, rocky, moderately dry slope in a sedge-forb meadow opening in an open *Pinus contorta, Abies lasiocarpa* forest, along the Old Boise Trail 101 just northeast of Hanson Cr., 6,800', 7/18/80.

LaZelle 8, ID, alpine slope at roadside ¼ mi east of Seven Devils Camp, 7,500', 8/29/63.

Packard 269, WS, dry slopes on Timbered Bench above Little Granite Cr., 6,000', 6/28/37.

Plus 25 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Camp Howard Triangulation Station to Black Lake, 6,050-8,100'.

Phacelia linearis (Pursh) Holz., Threadleaf Phacelia.

Uncommon (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,200-5,600'.

Baker 12159, ID, thickets, Wild Horse Saddle, on White Bird Ridge off Little Salmon River, 7/27/54.

Bingham and Miller 473, ID, main forks of Rapid River, sec. 26, T. 23 N., R. 1 W., in an open grass-forb stand on a south-facing, moderately dry, open, rocky hillside, 2,850', 6/8/82.

Plus 5 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, including Grave Point, along rd. 1819 at Caribou Cr., and Low Saddle, 5,250-5,625'.

Phacelia lyallii (Gray) Rydb., Lyall's Phacelia.

Rare, central Seven Devils, 7,600' ±. (Recommended for a "State Watch List" of plants rare in Idaho but not threatened unless major changes occur in local land use, cf. Steel and others 1981).

LaZelle 14, ID, along the rd. ¼ mi east of Seven Devils Camp, 7,500', 8/29/63.

Phacelia procera Gray, Tall Phacelia.

Scarce, southern Seven Devils, 5,000-6,400' ±.

Baker 11339, ID, edges of wood, 7 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Cusick 2346, WS, dry, stony mountainside on the Cuprum-Peacock Mine rd. (now rd. 106), 7,000', 9/15/1899.

Phacelia sericea (Grah.) Gray var. *ciliosa* Rydb., Silky Phacelia.

Common, central and southern Seven Devils, 6,500-8,300'.

Baker 12010, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 27 & 282, ID, and 105, ID and WS, west-facing, moist, meadow edge in opening of *Pinus albicaulis, Abies lasiocarpa* forest, ca. 0.1 mi southwest of Heavens Gate Lookout, 8,300', 7/21/79; south-facing, open, rocky lake ban along the north shore of Crater Lake, 6,550', 7/9/81; and south-facing, open, rocky slope with a sedge-forb stand, along rd. 517 at the Seven Devils Guard Station pasture fence cattle guard at the viewpoint looking up to Tower-of-Babel, 7,400', 7/13/80; respectively.

Brewer 17, IDF, Iron Springs Ranger Station, sec. 13, T. 22 N., R. 3 W. (at the spring ca. 0.2 mi north of Holbrook Saddle), 7,000' (actually 8,000'), 7/22/28.

Christ 12494, ID and WS, scattered timber and grassy slope, Seven Devils Camp, 7/12/41.

*Hermann 12049, ?NA, vicinity of Heavens Gate Lookout, 8,400', 8/6/55.

C. Johnson 9/2/83, BKR 2428, Plot 7076, *Festuca idahoensis-Phlox diffusa* community east of the Heavens Gate Lookout rd. ca. 1/3 mi south of the Lookout parking area, 7,930', 9/2/83.

Q. Jones 193, WS, moist meadow near receding snow, Heavens Gate, 7/11/50.

Ownbey and Meyer 2100, WS, open meadows, Heavens Gate, 6/27/40.

Packard 346 & 468, WS, near the summit of the ridge between the forks of Sheep Cr., 7,900'; and hillside near the head of the east fork of Sheep Cr., 7,200', 7/28/38; respectively.

St. John and Mullen 8608, WS, rock ledge, "Narrows" of Sheep Cr. (prob. The Narrows along trail 110), 6,800', 7/26/27.

Tisdale 7/14/78, IDF 79038, vicinity of Seven Devils Guard Station, 7,500', 7/14/78.

Plus 11 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Hypericaceae

Hypericum formosum H.B.K. var. *nortoniae* (Jones) Hitchc., the subalpine variety of Western St. Johnswort.

Scarce, northern Seven Devils, 6,500' ±.

Bingham Sight Record, drawn-down banks of Crater Lake, 6,500', 7/9/81.

Hypericum perforatum L., Klamath- or Goat-weed (European weed).

Frequent, entire Seven Devils, 5,000-6,900'.

Bingham 545, ID and WS, open, basalt-rock, southwest-facing slope near ridge at the edge of an open grass-forb-sagebrush stand, ca. 0.1 mi south of Cow Cr. Saddle along rd. 420, 5,240', 7/21/82.

Plus 9 Sight Records by Bingham and Miller, C. Johnson and Tisdale, Buckhorn Spring and Caribou Cr. to Old Timer Mine, 5,000-6,900'.

Iridaceae

Iris missouriensis Nutt., Western Blue Flag.

Scarce, southern Seven Devils, 5,300' ±.

Bingham and Miller 520, ID and WS, open sedge-forb meadow just east of Indian Cr. and just north of rd. 105 at old Landore, 5,330', 6/30/82.

oetaceae

Isoetes bolanderi Engelm., Bolander's Quillwort.
Scarce, central Seven Devils, 7,400' ±.
*Taylor 1673, WWB, shallowly submerged in Shelf Lake, 7,430', 9/17/67.

uncaceae

Juncus drummondii E. Mey. var. undet., Drummond's Rush.
Occasional, central and southern Seven Devils, 6,800-8,000'.
Baker 11307, ID, moist, shaded slope, Sheep Rock, 9/3/53.
Brewer 113, Council R.D., sec. 36, T. 22 N., R. 2 W. (prob. along trail 191 east of Pactolian Gulch), 7,000', 8/18/30.
*Christ 8662, ?NY, in meadow in cirque, Pyramid Peak, 8/8/37.
St. John and Mullen 8452, WS, creek bank, headwaters Bernard Cr., Dry Diggins, 7,300', 7/20/27.

Juncus mertensianus Bong., Merten's Rush.
Common, entire Seven Devils, 6,500-8,000'.
Bingham and Miller 39, 284, & 402, ID, bog at the north end of the pond at the northeast side of Sheep Lake at the foot of the Goat Pass manway, 7,880', 7/22/79; drawn-down north bank of Crater Lake, 6,550', 7/9/81; and open creek bottom ca. ¼ mi down Bridge Cr. from the outlet of Mirror Lake, 7,700', 7/26/81; respectively.
*Christ 8651, ?NY, in timber in cirque on Pyramid Peak, 8/8/37.
Hibbs 8/20/37, WS 108370, in spring below Hibbs Cow Camp, Dry Diggins, 8,000', 8/20/37.
St. John and Mullen 8492, WS, creek bank, headwaters Bernard Cr., Dry Diggins, 7,200', 7/20/27.
Plus 15 Sight Records by Bingham and Miller, Bernard Lakes and Dry Diggins Ridge to Black Lake, 7,200-8,000'.

Juncus parryi Engelm., Parry's Rush.
Uncommon, central and southern Seven Devils, 6,800-8,000'.
Baird 9/3/71, Council R.D., open meadow at head of Camp Cr. (fork of Indian Cr. heading at White Monument, 7,000', 9/3/71.
Baker 11307½, ID, moist, shaded slope, Sheep Rock, 9/3/53.
Christ 12587, ID, cliffs in cirque below Seven Devils Lake, 7/13/41.
Henderson 3863, ID, near the Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7/6/77.
C. Johnson 9/2/83, BKR 2434, Plot 7075, in a *Pinus albicaulis/Vaccinium scoparium-Juncus parryi* community ca. 0.1 mi southwest of Heavens Gate Lookout, 8,170', 9/2/83.
St. John and Mullen 8522, WS, rocky slope, Dry Diggins, 8,000', 7/22/27.
Plus 4 Sight Records by C. Johnson and Tisdale.

?*Luzula divaricata* Wats., Spreading Woodrush.
*Christ 12629, ?NY, timbered mountainside on trail (prob. 124) 2 mi north of Baldy Lake, 7/15/41 (but Idaho not in this species' geographic range).

Luzula hitchcockii Hamet-Ahti, Smooth Woodrush.
Common, central and southern Seven Devils, 5,900-8,400'.
Baker 12027 & 12090, ID, open alpine slopes, Seven Devils Camp, 7/21/54; and base of trees, steep rocky bank below Heavens Gate Lookout, 7/19/54; respectively.
Bingham and Miller 19, ID, and Bingham 334, ID and WS, open, subalpine *Abies lasiocarpa/Pinus albicaulis* forest on a west-facing slope, opening predominantly this species, ca. 0.1 mi southwest of Heavens Gate Lookout, 8,300', 7/21/79; and edge of moderately dense *Abies lasiocarpa/Picea engelmannii* forest on north shore of Black Lake, 7,200', 7/17/81; respectively.

*Christ 8677, ?NY, on high slopes and in meadows, Black Lake, 8/8/37.

Davis 2348, WS, wet soil under pine where snow had just melted, Smith Mt. Lookout, 7/3/40.

*Hermann 12047, ?NA, ?US, vicinity of Heavens Gate Lookout, 8,400', 8/6/55.

C. Johnson 8/14/83 & 9/2/83, BKR 2481 and 2432, Plot 3037, west of the Old Boise Trail ca. 1/3 mi southwest of Papoose Lake, *Pinus albicaulis/Luzula hitchcockii-Juncus parviflorus* community, 7,980', 8/14/83; and Plot 7074, ca. ¼ mi southwest of Heavens Gate Lookout, *Pinus albicaulis/Luzula hitchcockii* community, 8,150', 9/2/83; respectively.

St. John and Mullen 8525, WS, edge of snowbank, Dry Diggins, 8,000', 7/22/27.

Plus 21 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Luzula parviflora (Ehrb.) Desv., Small-flowered Woodrush.

Uncommon, northern and central Seven Devils, 5,000-6,800'.

Bingham 293, ID, rocky, drawn-down lakebed, north shore of Crater Lake, 6,550', 7/9/81.

C. Johnson 6/29/82, BKR 2033, Plot 789, above rd. 2060 ca. ¼ mi east of Kirkwood Cr., 5,220', 6/29/82.

Packard 284, WS, rotting log over Little Granite Cr. near fork at head, 5,000', 6/24-26/37.

Plus 2 Sight Records by Bingham and Miller.

?*Luzula piperi* (Cov.) Jones, Piper's Woodrush.

*Christ 12553 & 12564, ?NY, in lee of rocks on ridge, Heavens Gate, 7/12/41; and on open west slopes, Heavens Gate, 7/12/41; respectively (but the species is mainly from the Cascade Mts., south B.C., and south into Montana).

Luzula spicata (L.) DC., Spiked Woodrush.

Scarce, central Seven Devils, 8,000-9,000'.

Christ 12562, ID, timbered west slopes, Heavens Gate, 7/12/41.

St. John and Mullen 8547, WS, rock crevices on He Devil Mt., 9,000', 7/24/27.

Lamiaceae

Agastache urticifolia (Benth.) Kuntze var. *urticifolia*, Nettle-leaved Horse Mint.

Common, entire Seven Devils and Rapid River, 5,000-8,000'.

Baker 12268, ID, dry, gravelly west slope at Heavens Gate, 7/31/54.

Bingham and Miller 192 & 246, ID and WS, Douglas-fir forest of southeast-facing slope ca. 1/2-3/4 mi northeast of Hanson Cr. along the Old Boise Trail 101, 6,800', 7/18/80; and open *Abies lasiocarpa* forest along trail 192 ca. 1/3 mi northwest of Stevens Saddle, 7,600', 8/27/80; respectively.

*Christ 8600, ?NY, small draw, Placer Basin (along the Black Lake rd. 112), 8/8/37.

*Nelson and Nelson 3001, ?RM, Dry Diggins Lookout, 8/10-15/38.

Packard 430, WS, Hibbs Cow Camp, Dry Diggins area, 8,000', 7/26/38.

Plus 27 Sight Records by Bingham and Miller and C. Johnson, Camp Howard to Placer Basin, 5,000-7,600'.

Marrubium vulgare L., Horehound (Eurasian weed).

Scarce, Rapid River only, 2,200' +.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 in a disturbed grass-forb-weed stand ca. 0.1 mi up the trail from the Circle C State Fish Hatchery trailhead gate, 2,250', 6/8/82.

Monardella odoratissima Benth. var. *odoratissima*, Mountain Monardella.

Frequent, central and southern Seven Devils, 7,200-8,000'.

Bingham and Miller 200, ID and WS, south-facing moderately dry, extremely rocky, open slope with sandy loam between rocks, along the Old Boise Trail 101 ca. ¼ mi east of Horse Heaven Saddle, 7,200', 8/24/80.

Christ 12702, ID and WS, sliderock in west slopes along Sheep Cr., 7/17/41.

Kruckeberg 2838, WS and WTU, end of road from Riggins (rd. 517 at Windy Saddle), 8/26/51.

*Nelson and Nelson 2982, ?RM, rock slides, Silver Springs trail (possibly trail 111 along Morrison Ridge past the many springs en route to Silvers Adm. Site), 8/10-15/38.

Packard 429, WS, rock crevices in dry, open flat near Hibbs Cow Camp, Dry Diggins, 8,000', 7/26/38.

Wellner 1700, ID, slope northeast and above Little Baldy Lake, 7,200', 8/22/78.

Plus 8 Sight Records by Bingham and Miller, Dry Diggins Lookout to Joes Gap, 7,300-8,000'.

Prunella vulgaris L., Self-heal (prob. a Eurasian introduction).

Scarce (mostly at lower elevs.), central Seven Devils, 5,000' ±.

Bingham and Miller Sight Record, ca. ¼ mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, on the roadbank, 4,600', 8/17/82.

Salvia sclarea L., See-bright.

Scarce, lower southern Seven Devils, 5,000' ±.

Baird 6/19/72, Council R.D., along Kleinschmidt Grade just west of Cuprum, 5,000', 6/19/72 (prob. below 5,000').

Scutellaria angustifolia Pursh, Narrow-leaved Skullcap.

Occasional, northern Seven Devils and Rapid River, 5,100' ±.

Bingham and Miller Sight Records: ca. 1.1 mi up the lower Rapid River trail 113 from the Circle C State Fish Hatchery, 2,400', 6/8/82; and along the west fork Rapid River trail 113 just west of the main forks in sec. 26, 2,700', 6/8/82.

C. Johnson Sight Record, Plot 717, just southeast of Wild Horse Butte, 5,100', 5/25/82.

liaceae

Allium accuminatum Hook., Hooker's Onion.

Frequent, northern and central Seven Devils, 5,000-7,600' and Rapid River.

Baker 12045, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 67 & 365, ID, on bedrock outcrop immed. behind the Seven Devils Guard Station, 7,200', 7/24/79; and in an opening in a *Pseudotsuga menziesii, Abies lasiocarpa, Pinus contorta* south-slope stand ca. 0.1 mi up the Cannon Lake trail from the Old Boise Trail, 6,500', 7/27/81; respectively.

*Christ 12620, ?NY, on andesite (prob. Imnaha Basalt) knolls of dissected plateau, Hibbs Cow Camp, 7/15/41.

Ownbey and Meyer 2084, WS, gravelly exposed ridge, Hibbs Cow Camp, 6/26/40.

Packard 435, WS, dry soil above "The Swamps" on the trail to Hibbs Cow Camp, 7/27/38.

St. John and Mullen 8439, WS, gravel ridge, Bernard Cr. (vicinity of McGaffee Cow Camp), 5,600', 7/19/27.

Plus 4 Sight Records by Bingham and Miller.

Allium brandegi Wats., Brandegee Onion.

Occasional, northern and central Seven Devils, 6,500-7,800'.

Bingham and Miller 122, ID and WS, and 308, ID, southeast-facing *Pseudotsuga menziesii, Abies lasiocarpa, Pinus contorta* stand ca. 1/3 mi north-northeast of the Old Boise Trail where it crosses Hanson Cr., 7,400', 7/15/80; and on the open, weathered, reddish basalt immediately northeast across rd. 1819 from Cold Springs Cow Camp, 6,620', 7/10/81; respectively.

*Christ 12711, ?NY, basalt (Imnaha) scab outcrops near Lily Pad Lake, 7/17/41.

Packard 317, WS, vicinity of Hibbs Cow Camp, 7,800', 6/28/37.

Plus 1 Sight Record by Bingham and Miller, Cannon Lake trail.

***Allium tolmiei* Baker var. *platyphyllum* (Tidest.) Ownbey, the short-pediciled and long-scaped variety of Tolmie's Onion.

Rare, northern Seven Devils, 5,000' ± (recommended for a "Federal Watch List" of plants generally rare in the U.S., but not currently threatened unless major changes occur in local land use, Steele and others 1981).

Bingham and Miller 501, ID and WS, in deep basaltic soil sloughed off a steep, east-facing road cut ca. 0.8 mi southwards along rd. 420 from Cow Cr. Saddle, 5,360', 6/10/82.

F. Johnson 6/8/78, IDF 79428, on basalt scab, Cow Cr. Saddle, 6/8/78.

Plus 1 Sight Record by Bingham and Miller, and one collection by Steele, both below 5,000', vicinity of Pittsburg Saddle.

Allium tolmiei Baker var. *tolmiei*, the short-scaped variety of Tolmie's Onion.

Frequent, northern and central Seven Devils, 5,000-8,400'.

Aase 6/27/40, WS 273758, vicinity of Heavens Gate Lookout, 6/27/40.

Baker 12052, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Christ 12491, ID and WS, gravelly eroded slopes, Seven Devils Campground, 7/11/41.

Henderson 3848, ID, ca. ¼ mi northeast of Hibbs Cow Camp near th jct. of trails 56 and 112, 7/7/77.

F. Johnson 5/23/78, IDF 79092, open hillsides with pine, 1 mi west of Pittsburg Saddle, 5,000', 5/23/78.

Q. Jones 198, WS, soil patches on steep rocky slopes, Heavens Gate, 7/12/50.

Ownbey and Meyer 2085, WS, vicinity of Hibbs Cow Camp, 6/26/40.

Packard 331, WS, Dry Diggins area, 8,000', 6/29/37.

St. John and Mullen 8475, WS, gravelly ridge, Dry Diggins Area, 7,400', 7/20/27.

Brodiaea douglasii Wats., Douglas' Wild Hyacinth.

Frequent, northern and central Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller 191, ID and WS, in an open Douglas-fir stand on an east-facing slope ca. 1/2-3/4 mi north of Hanson Cr. along the Old Boise Trail 101, 6,800', 7/18/80.

Packard 579, WS, open grassy hillside near Low Saddle, 5/13/39.

Plus 13 Sight Records by Bingham and Miller, C. Johnson and Tisdale, Camp Howard Triangulation Station to head of Devils Farm Cr., 5,100-7,600'.

Calochortus elegans Pursh, Elegant Sego-Lily, or Cat's Ear.

Frequent, entire Seven Devils, 5,000-8,000'.

Bingham and Miller 176, ID and WS, open *Pseudotsuga menziesii* forest on east-facing slope along the Old Boise Trail 101 ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

*Christ 12518, ?NY, grassy east slope, Heavens Gate, 7/12/41.

*Hermann 12046, ?NA, 11½ mi southwest of Riggins above Shingle Cr. (prob. the north fork, along rd. 517), 8/6/55.

Lewis 2263, BOIS, OGDF, sec. 21, T. 20 N., R. 3 W., Cuprum rd., near Steele Stand 72-Pa-24 (along the Bear-Cuprum road 002, above Huntley Gulch), 5,700' (but Stand 72-Pa-24 is at 5,000'), 6/12/72.

Moore 98, WS, exposed places on ridge northeast of McGaffee Cow Camp, 8,600' (prob. nearer 5,500-6,000'), 5/16/36.

Ownbey and Meyer 2066, WS, loose soil, *Pinus-Pseudotsuga* forest, 7 mi above the mouth of Bernard Cr. (prob. along trail 56 or 57), 6/25/40.

Plus 8 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Calochortus eurycarpus Wats., Big-pod Mariposa Lily.

Frequent, central and southern Seven Devils, 5,000-7,800', (but visible mainly in certain flowering years).

Bingham 314, ID and WS, Bingham and Miller 369, ID, and 605, ID and WS, open Douglas-fir/Ninebark forest on south-facing rocky hillside, along rd. 105 ca. 0.8 mi south-southeast of

Landore at the jct. of rd. 105 and Indian Cr., 5,600', 7/16/81; open *Pseudotsuga menziesii* forest on south-facing, rocky hillside ca. 0.1 mi up the Cannon Lake trail from the Old Boise Trail, 6,500', 7/27/81; and on an open, rocky ridgetop immediately south of Lockwood Saddle east of rd. 108, 6,400', 7/27/83; respectively.

*Christ 8601 & 12619, NY, and 11070, ?NY, timbered mountainside, Placer Basin, 8/8/37; mountainside in Snake River Gorge west of Cuprum, 5/30/40; and on Andesite knoll of dissected plateau, Hibbs Cow Camp, 7/15/41; respectively.

Packard 459, WS, open flat, Hibbs Cow Camp, Dry Diggins, 7/27/38.

Plus 9 Sight Records by Bingham and Miller.

Calochortus macrocarpus Dougl., Sagebrush Mariposa Lily.

Scarce, lower central Seven Devils and Rapid River, 5,000' minus.

Baker 12160, ID, grassy hillside above Slaughter Gulch, White Bird Ridge off Little Salmon River, ? elev., 7/27/54.

Bingham and Miller 525, ID, open, overgrazed, grassy-weedy bench ca. 0.1 mi up the lower Rapid River trail 113 from the trailhead gate at the Circle C State Fish Hatchery, 2,250', 7/1/82.

***Calochortus nitidis* Dougl., Broad-fruited Mariposa Lily.

Rare, lower northern Seven Devils, 5,000-5,600' (recommended for a "Federal Watch List" of plants generally rare in the U.S. and State of Idaho, but not threatened unless major changes occur in local land use, cf. Steele and others (1981)).

Bingham 279B, ID, 532, ID and WS, and Bingham and Mason 547, ID and WS, open grass-forb-sagebrush stand on basaltic soil, immediately north of rd. 420 at Cow Cr. Saddle, 5,250', 7/8/81; exact same locality 7/21/82; and open grass-forb-sedge stand on rocky ridgetop, ca. 150' northeast of the Grave Point Lookout tower, 5,630', 7/21/82; and re-collected by Miss Holly Mason, the lookout, in late July or early Aug.; respectively.

Plus 1 Bingham and Miller Sight Record, open *Festuca idahoensis*/forb stand on grassy ridgetop, at Big Canyon Saddle, 5,000', 6/11/82.

Clintonia uniflora (Schult.) Kuntze, Bead Lily.

Uncommon, entire lower Seven Devils and Rapid River, 5,000-5,300'.

Baird 8/12/71, Council R.D., on Indian Cr. 2 mi below Landore, 5,000', 8/12/71.

Bingham and Miller 601, ID and WS, moderately dense, mature, *Abies grandis/Picea engelmannii* streambottom forest at the mouth of the unnamed creek entering the east fork of Sheep Cr. across trail 58 ca. 1 mi south of Log Cr., 5,100', 8/18/82.

Plus 4 Sight Records by Bingham and Miller and C. Johnson, Kirkwood Cr. to Old Landore and west fork Rapid River, 4,400-5,300'.

Disporum hookeri (Torr.) Nicholson var. *oreganum* (Wats.) Jones, Hooker's Fairy-bell.

Scarce, central Seven Devils, ? elev.

Baker 16799, ID, 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 5/24/65.

Disporum trachycarpum (Wats.) Benth. and Hook., Sierra Fairy-bell.

Uncommon, northern and central Seven Devils and Rapid River, 5,000-6,700'.

Bingham and Miller 159, ID, and 472, ID and WS, in a streambank opening of a moderately dense *Abies lasiocarpa, Picea engelmannii* forest in the bottom of Hanson Cr. just below the Old Boise Trail 101, 6,700', 7/17/80; and west-facing, shaded, bottom of the lower Rapid River in a moderately dense *Abies grandis, Pseudotsuga menziesii, Taxus brevifolia* forest along trail 113 about opposite the mouth of Blue Gulch, 2,400', 6/8/82; respectively.

Plus 3 Sight Records by Bingham and Miller and C. Johnson, lower west fork Rapid River, Wild Horse Butte, and Motthorn Saddle, 3,100-5,100'.

Erythronium grandiflorum Pursh var. *grandiflorum*, Glacier Lily.

Abundant, entire Seven Devils, 5,000-8,400'.

Baird 7/29/71, Council R.D., moist area at base of snowbank ¼ mi north of High Dive, 7,500', 7/29/71.

Bingham 339A, north-facing slope in a moderately dense *Abies lasiocarpa/Picea engelmannii* forest along trail 214 ca. 3/4 mi south of Emerald Lake, 7,220', 7/17/81.

Brewer 12, Council R.D., Iron Springs Camp, sec. 13, T. 22 N., R. 3 (?2) W., 8,000', 6/24/28.

*Christ 11059, 12575, 12586, & 12646, ?NY, near snowline under Douglas-fir and subalpine fir, Placer Basin (along rd. 112), north of Bear, 5/30/40; on banks of creek (fork of Bridge Cr.) from Seven Devils Lake, 7/13/41; on cliffs in cirque below Seven Devils Lake, 7/13/41; and on ridges by melting snowbank, Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41; respectively.

Davis 2530, WS, moist creek bottom, Black Lake, 7/3/40.

Q. Jones 205, ID, vicinity of Heavens Gate Lookout, 7/12/50.

Lewis 1287, OGDF, open ridgetop near pass north of Horse Mt., 5,000', 6/16/67.

Moore 102, WS, pine woods, McGaffee Cow Camp trail (110) in Bernard Cr., 8,600' (the Cow Camp is at 5,700'), 5/16/36.

*Munro 78, WS, Cow Camp at head of Bernard Cr. (McGaffee's), 4,000' (the Camp is at 5,700'), 5/15/37.

St. John and Mullen 8523, WS, Dry Diggins Area, 8,000', 7/22/27.

*St. John and Mullen 8530, ?WS, Dry Diggins Area, 8,000', 7/22/27.

Plus 33 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Fritillaria pudica (Pursh) Spreng., Yellow Bell.

Occasional (mostly at lower elevs.), entire Seven Devils, 5,000-5,300'.

Bingham 456, ID, open, basalt-rock ridgetop with a sagebrush-grass-forb stand immediately south of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.

Plus 3 Sight Records by Bingham and Miller and Steele (Big Canyon Saddle and along rd. 672 just north of Cow Cr. Saddle) and Steele (Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide), 5,000-5,250', (?____?).

Lloydia serotina (L.) Sweet, Alpine Lily.

Scarce, high, central Seven Devils, 7,800-9,000'.

Packard 350f, WS, moist alpine meadow near 4th Sheep Cr. Lake (Sheep Lake), 9,000' (but if near lake prob. nearer 7,825'), 7/25/38.

St. John and Mullen 8564, WS, wet rock crevices, He Devil Mt., 9,000', 7/24/27.

Smilacina racemosa (L.) Desf., Western False Solomon's Seal.

Common entire Seven Devils and Rapid River, 5,000-7,500'.

Baird 6/27/72, Council R.D., 2 mi below Placer Basin, 5,000', 6/27/72.

Bingham and Miller 137, ID and WS, east-facing, rocky, open, sedgy slope in an open *Abies lasiocarpa, Picea engelmannii, Pinus albicaulis* stand along the south side of Dog Cr. ca. 3/5 mi below Dog Lake, 7,500', 7/16/80.

Plus 21 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle south to Lockwood Saddle and Landore, 5,000-6,700'.

Smilacina stellata (L.) Desf., Star-flowered False Solomon's Seal.

Occasional, entire Seven Devils, 5,200-6,600'.

Bingham and Miller 524, ID and WS, level, open, sedgy bottom of Indian Cr. just northwest of the crossing of rd. 105 over Indian Cr., at Old Landore west of the spur-road to the smelter chimney, 5,330', 6/30/82.

Plus 3 Sight Records by C. Johnson: Plot 789, above rd. 2060 ca. ¼ mi east of Kirkwood Cr., 5,300', 6/29/82; Plot 790, above rd. 2060 just east of Kirkwood Cr., 5,300', 6/29/82; and Plot 7019, ca. 1¼ mi west of Echo Lake below trail 124, 6,610', 8/11/83.

Stenanthium occidentale Gray, Western Stenanthium.

Uncommon, central Seven Devils, 5,400-7,300'.

Baker 11999, ID, moist grassy bank, wooded slope 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 7/21/54.

Bingham and Miller 407, ID and WS, and 446, ID, northwest-facing, 4/5-shaded, moderately dense forest hillside in an *Abies lasiocarpa-Picea engelmannii* forest ca. 1/3 mi westward along trail 112 from the Windy Saddle trailhead, moderately moist soil near seeps, 7,100', 8/10/81; and east-facing, 2/3-shaded, moderately moist and densely forested hillside on the south bank of Ruth Lake, 7,250', 8/17/81 (with prominently red-edged tepals); respectively.

*Christ 12698, ?NY, moist places at crossing Sheep Cr. and trail (either the east fork or west fork of Sheep Cr. along trail 112), 7/17/41.

Packard 454, WS, wet, shaded streambanks where the Brundage Trail crosses the head of Sheep Cr., 6,600', 8/28/38.

St. John and Mullen 8389, WS, thicket in Bernard Cr. near McGaffee Cow Camp, 5,400', 7/17/27.

Streptopus amplexifolius (L.) DC. var. *chalazatus* Fassett, the glabrous-leaved variety of the Clasping-leaved Twisted-stalk.

Uncommon, central Seven Devils, 6,000-7,900'.

Bingham and Miller 396, ID, east-facing, steep, open rocky streambank, in the bottom of Bridge Cr. ca. 1/8 mi below Mirror Lake, 7,900', 7/26/81.

Bingham and Miller Sight Records: bottom of upper Bernard Cr. along trail 57, McGaffee Cow Camp watering hole, along trail 58 in the east fork of Sheep Cr. ca. 3/4 mi north of trail 112, along trail 113 at its jct. with trail 191 at Old Town 1/3 mi south of Rankin Mill, along trail 112 ca. 1/3 mi northwest of Windy Saddle, and along trail 124 in the Echo Lake fork of Little Granite Cr., 5,900-6,900'.

*Christ 12678, ?NY, creek bank at Sheep Cr. trail crossing (trail 112 prob. at the west fork of Sheep Cr.), 7/17/41.

Trillium ovatum Pursh, Wake Robin.

Frequent, entire Seven Devils and Rapid River, 5,000-5,700'.

Bingham 289, ID, southwest-facing slope with deep rocky loam in a 2/3-shaded *Pinus contorta-Pseudotsuga menziesii* forest, along the Old Boise Trail 101 ca. 0.7 mi northeast from the Lightning Ridge trail 52, 6,800', 7/9/81.

Bingham and Miller Sight Records: along trail 104 ca. 1/8 mi east of Big Canyon Saddle, 4,900', 6/11/82; along the east fork of Sheep Cr. trail 2¼ mi north of trail 112, 5,200', 8/18/82; along rd. 106 ca. 1 mi north of Lockwood Saddle, 6,600', 6/30/82; along rd. 517 ca. 1¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 5,200', 8/17/82; along rd. 672 ca. 1 mi northeast of Cow Cr. Saddle, 5,300', 6/10/82; and along west fork Rapid River trail 113 just east of Bridge Cr., 3,700', 6/8/82.

Howell 36, ID, 6 mi up the main fork of the Rapid River, 3/20/74.

Lewis 1285, OGDF, open conifer timber near Horse Mt., 5,000', 6/16/67.

Moore 100, WS, in leaf mold of alder thickets, McGaffee Cow Camp, 8,600'(the Cow Camp is at 5,700'), 5/16/36.

Sharsmith 4017, WS, near the summit of the ridge overlooking the upper basin of Sheep Cr., 5,500', 5/12/39.

Steele Sight Records: Stand 72-Pa-24, above Huntley Gulch along the Bear-Cuprum rd. 002, 5,000', 6/12/72; Stand 74-38, along rd. 517 below the south fork of Papoose Cr., 5,800', 8/8/74; and 2 stands (81-Pa-01A & 01B) along rd. 105, 6 mi north of Cuprum, 5,550', 6/24/81.

Veratrum californicum Durand var. *californicum*, False Hellebore.

Common, central and southern Seven Devils, 5,000-8,000'.

Bingham and Miller 358, ID, east-facing, open streambottom with a moist, sandy-gravelly-rocky loam soil edged by an open *Abies lasiocarpa-Picea engelmannii* forest in the bottom of Bridge Cr. ca. ¼ mi below Mirror Lake, 7,700', 6/26/81.

Christ 12718, ID, in marsh, Sheep Cr. Swamp, 7/17/41.

Packard 443, WS, moist mountain meadows, Lily Pad Lake, 7,500', 7/28/38.

St. John and Mullen 8498, WS, Dry Diggins Area, 7/20/27.

Plus 17 Sight Records by Bingham and Miller, C. Johnson, and Steele, Dry Diggins Ridge south to Huntley Gulch, 5,000-8,000'.

Xerophyllum tenax (Pursh) Nutt., Beargrass.

Frequent, central and southern Seven Devils, 5,000-7,600' (surprisingly, only 10 known occurrences in the Seven Devils, although common in the Gospel Mts. just northeast).

Bingham and Miller 567, ID, southeast-facing, 3/4-shaded, rocky bench under a moderately dense *Pinus contorta, Picea engelmannii, Abies lasiocarpa* stand ca. ¼ mi down rd. 517 from Shingle Cr., 6,850', 8/17/82.

*Christ 12669, ?NY, Squaw Cr. 14 mi southwest of Riggins (prob. along rd. 517 in Papoose or Shingle Cr.), 7/17/41.

Packard 447, WS, dry slope, Dry Diggins, 7/28/38.

*St. John and Mullen 8561, ?WS, open woods, He Devil Mt., 7/24/27.

Plus 6 Sight Records by Bingham and Miller, C. Johnson, and Steele, east fork Sheep Cr. trail 1¼ mi north of trail 112 south to Huntley Gulch, 5,000-7,600'.

Zigadenus elegans Pursh, Glaucous Death Camas.

Uncommon, mostly in the Gem-Sheep Lakes area, central Seven Devils, 7,600-8,000'.

Bingham and Miller 36 & 84, ID, in the open bog north of the pond at the northeast side of Sheep Lake at the foot of the Goat Pass manway, 7,880', 7/22/79; and in a 4/5-open, west-facing boulderfield along trail 123 bordering a *Pinus albicaulis-Abies lasiocarpa* stand, in the switchbacks ca. 1/8 mi west of the south end of Sheep Lake (same locality as Wellner 1692, below), 8,000', 7/25/79; respectively.

*Christ 12651, ?NY, soil pockets on ridges between Sheep Cr. Lakes No. 3 and 4 (Sheep and Gem Lakes), 7/16/41.

Wellner 1692, ID, in the boulderfield along trail 123 ca. 1/8 mi west of the south end of Sheep Lake, 8,000', 8/21/78.

Plus Bingham and Miller Sight Record, at the vernal pond along trail 123 ca. ½ mi southeast of Gem Lake, 7,600', 8/13/81.

Zigadenus paniculatus (Nutt.) Wats., Panicled Death Camas.

Scarce, central Seven Devils, 7,600' ±.

*Christ 12516, ?NY, open, grassy mountainside 1 mi east of Seven Devils Camp, 7/12/41.

Zigadenus venonosus Wats. var. *gramineus* (Rydb.) Walsh, the sheath-leaved variety of Meadow Death Camas.

Frequent, entire Seven Devils and Rapid River, 5,600-7,600'.

Baker 12049, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Q. Jones 217, ID and WS, low swales on grassy slopes, Heavens Gate, 7/13/50.

Moore 99, WS, along the Bernard Cr. trail 110 3 mi from the Snake River, 6,000' (prob. lower), 6/16/36.

Plus 13 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Camp Howard Triangulation Station south to Lockwood Saddle, and west fork Rapid River, 5,100-7,400'.

Limnanthaceae

Floerkea proserpinacoides Willd., False-mermaid.

Scarce, central Seven Devils, 7,300' ±.

St. John and Mullen 8476, WS, meadow on Dry Diggins, 7,300', 7/20/27.

Linaceae

Linum perenne L. var. *lewisii* (Pursh) Eat. and Wright, the western north American variety of Blue Flax.

Common, entire Seven Devils and Rapid River, 5,000-8,200'.

Baker 12284, ID, open, gravelly slopes west of Seven Devils Camp, 7/21/54.

Bingham and Miller 144, ID, and 344, ID and WS, east-facing, open rocky slope at edge of boulderfield, along the south side of Dog Cr. ca. 3/5 mi below the Lake, 7,500', 7/16/80; and south-facing, open, rocky hillside with bedrock outcroppings, along trail 218 ca. ½ mi west of the summit between Black Lake and Joes Gap, 7,800', 7/18/81; respectively.

*Christ 8606, ?NY, high, open mountainside, Smith Mt., 8/8/37.

Christ 12532, ID and WS, open east slopes of Heavens Gate, 7/12/41.

Q. Jones 197, ID and WS, open, rocky hillside near Heavens Gate Lookout, 7/12/50.

Ownbey and Meyer 2067, WS, headwaters of Sheep Cr. (along trail 112), 6/26/40.

Packard 330, WS, head of the north fork of Bernard Cr. above McGaffee Cow Camp, 5,400', 6/29/37.

St. John and Mullen 8484, WS, gravelly ridge, Dry Diggins, 7,200', 7/20/27.

Tisdale 7/17/79, IDF 80180, Plot 95, Seven Devils Guard Station pasture, 7,600', 7/17/79.

Plus 16 Sight Records by Bingham and Miller, and C. Johnson.

oasaceae

Mentzelia dispersa Wats., Small-flowered Mentzelia.

Scarce, central Seven Devils, 6,800-8,000'.

*Christ 12706, ?NY, sliderock in west slopes along Sheep Cr. trail, 7/17/41.

Ownbey and Meyer 2071, WS, headwaters of Sheep Cr., 6/26/40.

alvaceae

Iliamna rivularis (Dougl.) Greene var. *rivularis*, Streambank Globemallow.

Uncommon, central Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller 374, ID and WS, open brushfield in an old burn, ca. 0.2 mi down the Cannon Lake trail from Lower Cannon Lake, 7,000', 7/27/81.

Bingham and Miller Sight Records, along the lower Rapid River trail 113 ½ mi above the Circle C State Fish Hatchery, 2,280', 6/8/82; along the Old Boise Trail 101 ca. 3/4 mi north of Hanson Cr., 6,800', 7/27/81; along rd. 517 ca. 0.6 mi above its 2d crossing of Papoose Cr. in sec. 22, 5,000', 8/17/82; and along trail 124 in the head of Fall Cr. west of Potato Hill, 7,600', 8/15/81.

Malva neglecta Wallr., Dwarf Mallow (introduced European weed).

Scarce (mostly from lower elevs.), central Seven Devils and Rapid River, 5,000' ±.

Bingham and Miller 581, ID, gravel roadbed of road 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Bingham and Miller Sight Record, along the west fork Rapid River trail 113 in the McCrea Place pasture, 4,000', 6/9/82.

Sidalcea neomexicana Gray var. *crenulata* (Nels.) Hitchc., Rocky Mountain Checker Mallow.

Scarce, southern Seven Devils, 5,100' ±.

Lewis 2280, BOIS, OGDF, sec. 21, T. 20 N., R. 3 W., Cuprum rd. (105), on Steele Stand 72-Pa-25, 5,130', 6/12/72.

Steele Sight Record, same locality and date.

ymphaceae

Nuphar polysepalum Engelm., Indian Yellow Pond Lily.

Occasional, central Seven Devils, 7,200-7,300' ±.

Bingham and Miller 259, ID and WS, in shallow water in the two westernmost of the Bernard Lakes, 7,200', 8/28/80.

St. John and Mullen 8582, WS, Lily Pad Lake, Dry Diggins, 8,000' (actually the Lake is at 7,300'), 7/25/27 (still observed there by Bingham and Miller in 1981).

Onagraceae

Circaea alpina L., Enchanters Nightshade.

Scarce, central Seven Devils, 5,000-5,100'.

Bingham and Miller 589, ID and WS, in a cutover creek bottom ca. ½ mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, 4,900', 8/17/82.

Bingham and Miller Sight Record, along the east fork of Sheep Cr. trail 58 ca. 1 mi south of Log Cr., 5,100', 8/18/82.

Clarkia pulchella Pursh, Deer-horn Clarkia.

Uncommon (mostly at lower elevs.), northern and central Seven Devils and Rapid River, 5,000-6,600'.

Aldrich 7/5/07, ID 3600, Camp Howard (prob. the Cow Camp), 7/5/07.

*Baker 11911, ?ID, open woods, Seven Devils rd. 4 mi west of Riggins (prob. along rd. 517 in Papoose Cr.), ?elevation, 7/21/54.

Bingham 555, ID and WS, in an open grass-forb stand ca. 150' east of the Grave Point Lookout tower, 5,600', 7/21/82.

Plus 7 Sight Records by Bingham and Miller, C. Johnson, and Steele, Cow Cr. Saddle to Old Timer Mine, 5,200-6,600'.

Clarkia rhomboidea Dougl., Common Clarkia.

Occasional, central and southern Seven Devils and Rapid River, 5,000-5,200'.

Bingham and Miller 595, ID and WS, in an open *Pinus ponderosa* stand on a Douglas-fir/ninebark h.t., ca. 1.0 mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, 5,150', 8/17/82.

Brewer 61, Council R.D., mouth of Paradise Cr. (on main fork of Rapid River), sec. 15 (?27), T. 22 N., R. 1 W., 4,000', 6/27/29.

Steele Sight Record, Stand 72-Pa-25, at the Bear-Indian Crs. divide along the Bear to Cuprum rd. 002, 5,130', 6/12/72.

Epilobium alpinum L. var. *alpinum*, Alpine Willow-weed.

Uncommon, central and southern Seven Devils, 7,200-8,000'.

Bingham 322, ID, and Bingham and Miller 381, ID and WS, in the campground, moist gravelly soil, northwest shore of Black Lake, 7,200', 7/17/81; and southeast-facing, open grass-forb stand on a rocky hillside bordering Dog Cr. ca. 0.2 mi below Dog Lake, 7,900', 7/28/81 (intermed. with var. *nutans*); respectively.

Christ 8639, ID, shore of Black Lake, 8/8/37.

*Christ 8664, 8679, 12590, 12611, 12613, & 12731, ?NY, (8664) grassy slopes of Pyramid Peak, 8/8/37; (8679) edge of pool in tundra, Pyramid Peak, 8/8/37; (12590) cliffs in cirque below Seven Devils Lake, 7/13/41; (12611) moist bank of Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41; (12613) moist bank of Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41; and (12731) in marsh, Sheep Cr. swamp, 7/17/41; respectively.

Epilobium alpinum L. var. *clavatum* (Trel.) Hitchc., the subclavate-capsuled variety of Alpine Willow-weed.

Occasional, central Seven Devils, 7,500-9,000'.

Bingham and Miller 64, ID, in the steep, long, loose-rock talus 0.1 mi southeast of Goat Pass about ¼ of the way down the talus to Mirror Lake, 8,300', 7/24/79.

Kruckeberg 3195, WS, WTU, loose scree above Sheep Cr. Lake No. 2 (Shelf Lake), 7,500', 7/31/52.

Packard 465, WS, rock crevices along the Brundage Trail near the summit between the forks of Sheep Cr., 7,900', 7/28/38.

St. John and Mullen 8551, WS, moist rock chimney, He Devil Mt., 9,000', 7/24/27.

Epilobium alpinum L. var. *lactiflorum* (Hausskn.) Hitchc., the white-or cream-petaled variety of the Alpine Willow-weed.

Scarce, central and southern Seven Devils, 6,800-7,200'.

*Baker 12060, ?ID, wet, marshy ground about spring, Seven Devils Guard Station, 7/21/54.

C. Johnson Sight Record, Plot 7069, west of the Deep Cr. trail 219 ca. ½ mi west of the Black Lake rd. 112 at High Dive, 6,760', 8/31/83.

Epilobium alpinum L. var. *nutans* (Hornem.) Hook., the short-petioled variety of Alpine Willow-weed.

Common, central and southern Seven Devils, 6,400-8,000'.

Bingham and Miller 368 & 401, ID, wet soil of bank of Bridge Cr. ca. 1 mi below Seven Devils Guard Station along the Old Boise Trail 101, 6,600', 7/27/81; and steep, rocky, east-facing streambank ca. ¼ mi down Bridge Cr. from the outlet of Mirror Lake, 7,700', 7/26/81; respectively.

*Christ 12732, ?NY, in marsh, Sheep Cr. swamp, 7/17/41.

Hibbs 8/20/37, WS, in a spring, Hibbs Cow Camp, 7/20/37.

St. John and Mullen 8587, WS, marshy shore of Lily Pad Lake, 8,000', 7/25/27.

Plus 18 Sight Records by Bingham and Miller, Dry Diggins Ridge and Bernard Lakes to Emerald Lake, 6,400-7,600'.

Epilobium angustifolium L., Fireweed.

Common, entire Seven Devils, 5,000-8,000'.

*Baker 11330, ?ID, open woods about spring 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham and Miller 586, ID and WS, alongside rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

St. John and Mullen 8554, WS, woods, He Devil Mt., 8,000', 7/24/27.

Plus 37 Sight Records by Bingham and Miller, C. Johnson, Steele, and Tisdale, Cold Springs Lookout site to Lockwood Saddle and Landore, 5,500-8,000'.

Epilobium glaberrimum Barbey var. *fastigiatum* (Nutt.) Trel., the low var. of Smooth Willow-weed.

Uncommon, central and southern Seven Devils, 6,900-7,600'.

Bingham 321, ID, and Bingham and Miller 449, ID and WS, along campground rd., northwest shore of Black Lake, 7,200', 7/17/81; and southeast shore of Horse Heaven Lake, 7,600', 8/18/81; respectively.

Plus 4 Sight Records by Bingham and Miller, Seven Devils Campground to Emerald Lake, 6,900-7,800'.

Epilobium glandulosum Lehm. var. *glandulosum*, Common Willow-weed.

Scarce, central Seven Devils, 6,800-7,200'.

Bingham and Miller 239 & 367, ID and WS, in small marsh ca. 0.1 mi down the Ruth Lake Trail from the Lake, 7,200', 8/27/80; and along the Old Boise Trail 101 in Bridge Cr. ca. 1 mi below Seven Devils Guard Station, 6,800', 7/27/81; respectively.

Epilobium minutum Lindl., var. undet., Small-flowered Willow-weed.

Occasional, central Seven Devils, 5,000-8,500'.

Bingham and Miller 53 & 87, ID, and 579, ID and WS, south-facing, open slope of gravelly loam in the large boulderfield at the foot of the long talus slope between Tower of Babel and She Devil Mt., ca. 0.2 mi east of Sheep Lake, 8,075', 7/23/79; northeast-facing foot of northwest ridge off He Devil Mt., on open, sometimes slipping, gravelly-rocky slope, 8,450', 7/26/79; and rock-gravelly loam soil on north-facing roadcut ca. ¼ mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82; respectively.

Plus 2 Sight Records by Bingham and Miller, south end of East fork Sheep Cr. trail 58 and Dog Cr. ½ mi below mouth, 7,000-7,800'.

Epilobium paniculatum Nutt. var. undet., Tall Annual Willow-weed.

Uncommon, northern and central Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller Sight Records: along trail 110 ca. 0.1 mi east of McGaffee Cow Camp, 5,800', 8/12/81; along the Old Boise Trail 101 ca. 3/4 mi below Seven Devils Guard Station, 6,700', 7/27/81; along the west fork Rapid River trail 113 at Old Town (abandoned mining town), ca. 1/3 mi south of Rankin Mill, 6,200', 8/16/81; and along the Old Boise Trail ca. ¼ mi east of Horse Heaven Saddle, 7,600', 8/18/81.

C. Johnson Sight Records: Plot 786, just north of Caribou Cr. ca. ½ mi down the creek from rd. 2060, 5,260', 6/27/82; and Plot 793, just southwest of Grave Point Lookout, 5,550', 6/29/82.

Tisdale Sight Records: Plot sites 73 and 74, vicinity of Low Saddle, 5,200', 7/13/78; Plot sites 90 and 91, vicinity of Cold Springs Cow Camp, 6,600', 7/13/79; and Plot site 95, Seven Devils Guard Station pasture, 7,360-7,600', 7/15-17/79.

Epilobium watsonii Barbey var. *occidentale* (Trel.) Hitchc., the glandular inflorescensed variety of Watson's Willow-weed.

Scarce, southern Seven Devils, 6,500' ±.

Baker 11332, ID, moist soil about spring 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Gayophytum decipiens Lewis and Szeyk., Deceptive Groundsmoke.

Frequent, central Seven Devils, 6,800-7,900'.

Bingham 146 & 218B, ID and WS, and 382, ID, open *Pinus contorta* forest along the Old Boise Trail just north of Hanson Cr., 6,800', 7/17/80; open, rocky-gravelly sedge-forb meadow in the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. Line, 7,850', 8/27/80; and open, southeast-facing rocky hillside ca. 0.2 mi down the Dog Lake manway from the lake, 7,900', 7/28/81; respectively.

Plus 9 Bingham and Miller Sight Records, Heavens Gate and Dry Diggins Lookouts to Carbonate Hill, 6,800-7,900'.

Gayophytum humile Juss., Dwarf Groundsmoke.

Occasional, entire Seven Devils, 5,000-7,600'.

Baird 9/8/71, Council R.D., open area ½ mi from Horse Mt. Lookout, 7,000', 9/8/71.

Baker 11300 & 12028, ID, Kinney Point, 9/3/53; and open, alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham 292B, ID, in an open *Pinus ponderosa* stand at the campground area of Low Saddle, 5,400', 7/8/81.

St. John and Mullen 8447, WS, dry flats on Dry Diggins, 7/20/27.

Gayophytum racemosum Torr. and Gray, Racemed Groundsmoke.

Occasional, central and southern Seven Devils, 6,500-7,800'.

Baker 11327, ID, moist ground about spring 6 mi north of Cuprum, 9/3/53.

*Christ 8659 & 12720, ?NY, in meadow in cirque, Pyramid Peak, 8/8/37; and in basalt scab outcrops near Sheep Cr. swamp, 7/17/41; respectively.

Oenothera flava (Nels.) Garrett, Long-tubed Evening Primrose.

Scarce, southern Seven Devils, 5,300' ±.

Bingham and Miller 523, ID and WS, open sedge meadow in wide bottom of Indian Cr. just north of the old brick smelter chimney at old Landore, west side of Indian Cr., just north of rd. 105, 5,330', 6/30/82.

Orchidaceae

Calypso bulbosa (L.) Oakes, Fairy Slipper.

Frequent, northern and central Seven Devils + Rapid River, 5,000-6,800'.

Baker 16797, ID, 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 5/24/65.

Moore 90, WS, under trees at McGaffee Cow Camp, 8,600' (actually the Cow Camp is at 5,700'), 5/16/36.

Plus 8 Sight Records by Bingham and Miller and C. Johnson, Motthorn Saddle to Hanson Cr., 5,000-6,800'.

Corallorhiza maculata Raf., Spotted Coral-root.

Scarce, northern and central Seven Devils, 5,300-6,800'.

Bingham and Miller 174, ID and WS, moderately dense *Abies lasiocarpa-Pinus contorta-Pseudotsuga menziesii* forest on southeast-facing slope along the Old Boise Trail 101 ca. 3/4 mi north of Hanson Cr., 6,800', 7/18/80.

C. Johnson Sight Record, Plot 787, below rd. 1819 just south of Low Saddle, 5,350', 6/27/82.

Corallorhiza striata Lindl., Striped Coral-root.

Scarce, northern Seven Devils, 5,200' ±.

C. Johnson 6/29/82, BKR 2035, Plot 789, above rd. 2060 ca. ¼ mi east of Kirkwood Cr., 5,220', 6/29/82.

Corallorhiza trifida Chat., Yellow Coral-root.

Occasional, central Seven Devils, 5,400-6,700'.

Bingham and Miller 164, ID, dense *Abies lasiocarpa/Picea engelmannii* stand in the bottom of Hanson Cr. just below the Old Boise Trail 101, 6,700', 7/17/80.

St. John and Mullen 8429, WS, in woods along Bernard Cr., 5,400', 7/19/27.

Plus 1 Sight Record by Bingham and Miller, along trail 124 in the head of the south fork of Little Granite Cr., 6,600', 8/14/81.

***Eburophyton austiniae* (Gray) Heller, Ghost Orchid.

Rare, west Fk. of Rapid River, 4,500' ± (recommended for a "State Watch List" of plants rare in the State of Idaho but not threatened unless major changes occur in local land use [cf. Steele and others, 1981]).

Bingham and Miller 497, ID, southeast-facing, moderately dense *Pseudotsuga menziesii, Abies grandis, Pinus contorta* forest on gravelly-loam trailbank along trail 113 in the west fork of the Rapid River ca. 0.2 mi above Hanson Cr., 4,450', 6/9/82.

Goodyera oblongifolia Raf., Western Rattlesnake Plantain.

Abundant, entire Seven Devils and Rapid River, 5,000-7,200'.

Bingham and Miller 165, ID, dense, streambottom *Abies lasiocarpa/Picea engelmannii* forest ca. ¼ mi below the Old Boise Trail at Hanson Cr., 6,700', 7/17/80.

St. John and Mullen 8397, WS, woods, McGaffee Cow Camp, 5,400', 7/17/27.

Plus 39 Sight Records by Bingham and Miller, C. Johnson, and Steele, Kirkwood Cr. to Black Lake, 5,200-7,300'.

Habenaria dilitata (Pursh) Hook. var. *leucostachys* (Lindl.) Ames., the long- and slender-spurred variety of White Bog-orchid.

Occasional, northern and central Seven Devils, 5,000-7,300'.

Bingham 305, ID, west-facing streambank in open *Abies lasiocarpa* forest, Caribou Cr. along rd. 1819 east of Low Saddle, 6,200', 7/10/81.

Bingham and Miller Sight Records: along the Old Boise Trail 101 in the Seven Devils Lake fork of Bridge Cr., 7,000', 7/27/81; along trail 113 ca. ½ mi east of its jct. with 192 north of Carbonate Hill, 7,300', 8/16/81; and along the east fork of Sheep Cr. trail 58 ca. 1 mi north of Log Cr., 5,100', 8/18/82.

Habenaria elegans (Lindl.) Boland, Hillside Rein-orchid.

Occasional, central Seven Devils, 5,800-7,300'.

Bingham and Miller 395, ID, northeast-facing, rocky slope in a half-open *Abies lasiocarpa/Pinus contorta* forest in the Seven Devils Lake fork of Bridge Cr. ca. ¼ mi south-southwest of the Seven Devils Guard Station, 7,300', 7/6/81.

Bingham and Miller Sight Records: along the east fork Sheep Cr. trail 58 ca. 1½ mi north of Log Cr., 5,800', 8/18/82; and along the tote road (lower) part of trail 113 ca. ½ mi above its jct. with trail 192 south of Rankin Mill, 6,800', 8/16/81.

Habenaria obtusata (Banks) Richards., One-leaf Rein-orchid.

Scarce, Rapid River only, ? elev.

Tucker 7/17/32, ID 7362, Rapid River, ? elev., 7/17/32.

Habenaria saccata Greene, Slender Bog-orchid.

Scarce, central Seven Devils, 7,200' ±.

Bingham and Miller 327, ID and WS, and 441, ID, both from the identical locality but in successive years, small, shady bog along the Ruth Lake trail ca. 0.1 mi east of the Lake, 7,200', 8/28/80 and 8/17/81, respectively.

Habenaria unalascensis (Spreng.) Wats., Alaskan Rein-orchid.

Occasional, central Seven Devils, 6,600' ±.

*Christ 12623 & 12685, ?NY, on Douglas-fir slopes 2 mi south of Hibbs Cow Camp on trail (prob. 124) to Baldy Lake, 7/15/41; and timbered slopes along Sheep Cr. trail (prob. 112), 7/17/41; respectively.

Packard 450, WS, wet shaded streambank where Brundage Trail crosses the head of Sheep Cr. (trail 112 in the west fork), 6,600', 7/28/38.

Listera caurina Piper, Northwestern Twayblade.

Uncommon, central and southern Seven Devils, 6,300-7,200'.

Baker 12095 & 12256, ID, shaded woods 11 mi west of Riggins (prob. on McClinery Ridge along rd. 517), 7/21/54; and moist woods along Shingle Cr. (prob. the north fork along rd. 517), 7/31/54; respectively.

Bingham and Miller 414, ID and WS, north-facing, shady hillside in the bottom between the forks of the west fork of Sheep Cr. along trail 112, 6,800', 8/10/81.

*Christ 12637, ?NY, timbered mountainside, 1 mi north of Baldy Lake, 7/15/41.

Christ 12682, ID, open floor of dense timber, Sheep Cr. trail 112, 7/17/41.

Plus 3 C. Johnson Sight Records, Old Boise Trail 101 south of Hanson Cr., along trail 214 south of Emerald Lake, and along rd. 112 east of Black Lake, 6,760-7,200'.

Listera cordata (L.) R. Br., Heart-leaf Twayblade.

Occasional, central Seven Devils and Rapid River, 5,000-6,800'.

Bingham and Miller 413, shady streambottom in *Picea engelmannii-Abies lasiocarpa-Pinus contorta* forest ca. 0.1 mi southwest of the jct. of trail 112 with the east fork of the west fork of Sheep Cr., 6,800', 8/10/81.

Bingham and Miller Sight Records: along the Ruth Lake trail 189 ca. ¼ mi northeast of the lake, 7,100', 8/17/81; and along the west fork Rapid River trail 113 ca. 0.2 mi above Hanson Cr., 4,400', 6/9/82 and at Rankin Mill, 5,900', 8/16/81.

Orobanchaceae

Orobanche fasciculata Nutt., Clustered Broomrape.

Uncommon, entire Seven Devils, 5,000-7,600'.

Bingham 273 and Bingham and Miller 379, ID, open, shallow-soiled ridgetop over basalt, with *Agropyron spicatum/Koeleria cristata* h.t., grass-forb-rigid sage stand, just north of rd. 420 at Cow Cr. Saddle, 5,260', 8/8/81; and on open, decomposed ? basalt ca. 100' southwest of Windy Saddle, 7,600', 7/27/81; respectively.

Bingham and Miller Sight Records: along rd. 108 ca. ¼ mi southwest of Lockwood Saddle, 6,500', 6/27/83; at Sawpit Saddle, 5,050', 7/8/81; and along rd. 672 just north of Cow Cr. Saddle, 5,300', 6/10/82.

Orobanche uniflora L. var. *purpurea* (Heller) Achey, the woolly-anthered variety of Naked Broomrape.

Scarce, northern Seven Devils, 5,000' ±.

Bingham and Miller 508, ID and WS, open, southeast-facing, rocky hillside with an open grass-forb stand in the *Agropyron spicatum/Festuca idahoensis* h.t., along trail 104 ca. 150' north of Big Canyon Saddle, 5,050', 6/11/82.

Orobanche uniflora L. var. undet., Naked Broomrape.

*Christ 12448 & 12618, ?NY, on cliffs above Seven Devils Lake, 7/11/41; and on promontory jutting into Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41; respectively.

Paeoniaceae

Paeonia brownii Dougl., Brown's Peony.

Uncommon, entire Seven Devils, 5,000-6,800'.

Bingham 283, ID, and Bingham and Miller 519, ID and WS, west-facing, open hillside with a deep rocky loam soil and an open grass-forb stand in the *Agropyron spicatum/Koeleria cristata* h.t., 200 yds. east of the Old Boise Trail 101 ca. 3/5 mi south of the trailhead along rd. 1819 southeast of Cold Springs Lookout, 6,825', 7/9/81; and in an open grass-forb-sedge meadow near the ridgetop along the Black Lake rd. 112 ca. 1½ mi southward from Placer Basin, 5,850', 6/30/82; respectively.

Christ 8592, ID, basalt scabland 6 mi north of Bear, Adams Co., 8/8/37.

Moore 101, WS, ridge southeast of McGaffee Cow Camp, 8,600' (prob. nearer 6,000' since the Cow Camp is at 5,700'), 5/16/36.

Peters and Moore 135, WS, gravelly soil near McGaffee's Cow Camp, head of north fork of Bernard Cr., 5,000', 5/16/36.

Plus 3 Sight Records by Bingham and Miller and Steele, Camp Howard Triangulation Station to Landore and Bear-Indian Crs. divide, 5,100-5,900'.

Pinaceae

Abies grandis (Dougl.) Forbes, Grand Fir.

Common, encircling entire Seven Devils below 6,800' and along lower Rapid River.

Bingham 537, ID and WS, Grand fir-Huckleberry h.t. in regenerating, ridgetop clearcut, along rd. 420 south of Cow Cr. Saddle and 0.2 mi south of rd. 421, 5,400', 7/21/82.

Plus 30 Sight Records by Bingham and Miller, C. Johnson and Steele, Big Canyon Saddle to Landore, 5,000-6,800'.

Abies lasiocarpa (Hook.) Nutt., Subalpine Fir.

Abundant, commonest tree of the central Seven Devils, generally above 6,500', to the tops of He and She Devil Mts. (almost 9,400'), and in Rapid River below Rankin Mill.

Baker 12290, ID, Rocky Mt. slopes west of Seven Devils Camp, 7/31/54.

Bingham 332, ID and WS, subalpine fir-Grouse Whortleberry h.t. on the densely forested northwest shore of Black Lake, 7,200', 7/17/81.

Christ 8715, ID, slopes and high ridges surrounding Black Lake, 8/8/37.

Meyer 850, WS, above Bernard Cr. near McGaffee Cow Camp, 5,000', 5/13/37.

Munro 74, WS, rocky saddle north side of Seven Devils Mts., 5,750', 5/14/37.

St. John and Mullen 8503, WS, Dry Diggins, 7/20/27.

Plus 75 Sight Records by Bingham and Miller, C. Johnson and Steele.

Larix occidentalis Nutt., Western Larch.

Frequent, entire Seven Devils and Rapid River, 5,000-7,100'.

Bingham 536, ID and WS, gentle, northeast-facing slope in clearcut near ridgetop, *Pseudotsuga menziesii, Abies grandis, Pinus ponderosa* regeneration on area, along rd. 420 ca. 0.2 mi south of its jct. with rd. 241 ½ mi south of Wickiup Butte, 5,400', 7/21/82.

Plus 14 Sight Records by C. Johnson, Steele, Wellner, Bingham and Miller, Caribou Cr. to Landore and Lockwood Saddle, 5,000-7,100'.

Picea engelmannii Parry, Engelmann Spruce.

Abundant, entire Seven Devils and Rapid River, 5,000-7,900'.

*Christ 12484, ?NY, ridges, Seven Devils Ridge, 7/11/41.

St. John and Mullen 8502, WS, dry woods, Dry Diggins, 7,000', 7/20/27.

Wellner 1702, ID and IDF, banks of Little Baldy Lake, 7,400' (actually 7,200'), 8/22/78, a compact, dwarf form.

Plus 64 Sight Records by Bingham and Miller, C. Johnson, and

Steele, Cow Cr. Saddle and Kirkwood Cr. to Black Lake and Joes Gap, 5,000-7,800', including west fork Rapid River.

Pinus albicaulis Engelm., Whitebark Pine.

Abundant, central and southern Seven Devils, 6,800-9,400'.

Baker 12292, 11319, & 12036, ID, summit of Kinney Point (7,125'), Hells Canyon, 9/3/53; wooded slopes 6 mi north of Cuprum (prob. along rd. 106), 9/3/53; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 197, ID, southwest-facing, open, subalpine forest of *Pinus albicaulis* and *Abies lasiocarpa* on the main Snake-Salmon Rivers divide ca. 0.1 mi southwest of Heavens Gate Lookout, 8,400', 7/19/80 (collection contains an aecial-stage *Cronartium ribicola* Fisch. ex Rabenh. branch canker).

*Christ 8617 & 12527, ?NY, slopes and high ridges surrounding Black Lake, 8/8/37; and, in colonies in ravines and on benches, Heavens Gate, 7/12/41; respectively.

St. John and Mullen 8442, WS, Dry Diggins, 7,500', 7/20/27.

Plus 39 Sight Records by Bingham and Miller and C. Johnson.

Pinus contorta Dougl. var. *latifolia* Engelm., Inland Lodgepole Pine.

Abundant, entire Seven Devils and Rapid River, 5,000-7,700'.

Baker 11296 & 12024, ID, north slope of Kinney Point, 9/3/53; and Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 569, ID and WS, southeast-facing, rocky bench with a moderately dense *Pinus contorta, Picea engelmannii, Abies lasiocarpa* forest, ca. ¼ mi down rd. 517 from the north fork of Shingle Cr., 6,850', 8/17/82.

St. John and Mullen 8501, WS, Dry Diggins area, 7,200', 7/20/27.

Plus 52 Sight Records by Bingham and Miller, C. Johnson, and Steele, Caribou Cr. and Cold Springs Lookout site to Landore and Lockwood Saddle, 5,350-7,900'.

Pinus ponderosa Dougl., Western Yellow or Ponderosa Pine.

Common (at lower elevs.), entire Seven Devils and Rapid River, 5,000-7,200'.

Bingham and Miller 546, ID, north-facing, rocky-gravelly roadcut in an open Douglas-fir/ninebark h.t. ca. ¼ mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Plus 33 Sight Records by Bingham and Miller, C. Johnson, and Steele, Wild Horse Butte and Big Canyon Saddle to Huntley Gulch, 5,000-7,200'.

Pseudotsuga menziesii (Mirb.) Franco var. *glauca* (Beissn.) Franco, Inland Douglas-fir.

Abundant, entire Seven Devils and Rapid River, 5,000-7,900'.

Bingham and Miller 553, ID and WS, north-facing, rocky-gravelly roadbank along rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

*Christ 12679, ?NY, Sheep Cr., 7/17/41.

Plus 65 Sight Records by Bingham and Miller, C. Johnson, and Steele, Wild Horse Butte and Big Canyon Saddle to Huntley Gulch, 5,000-7,900'.

Plantaginaceae

Plantago lanceolata L., English Plantain (European weed).

Scarce, lower Rapid River only, 2,200' ±.

Bingham and Miller 528, ID, in the rocky roadbed at the trail 113 trailhead gate at the southwest end of the Circle C State Fish Hatchery, 2,200', 7/1/82.

Plantago major L. var. *major*, Common Plantain (prob. a Eurasian introduction).

Occasional, northern and central Seven Devils, 5,000-6,800'.

Bingham and Miller 575, ID and WS, in the rocky-gravelly roadbed of rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Plus 4 Sight Records by Bingham and Miller, south of Cow Cr. Saddle, east of Low Saddle, Old Boise Trail near Cannon Cr. and McGaffee Cow Camp, 5,300-6,800'.

Agropyron caninum (L.) Beauv. ssp. *majis* (Vasey) Hitchc. var. *andinum* (Scribn. and Smith) Hitchc., Bearded Wheatgrass.

Scarce to Uncommon, southern Seven Devils, 6,800-8,000'.

*Christ 8609, ?NY, high, open side of Smith Mt., 8/8/37.

C. Johnson 8/31/83, BKR 2582, Plot 7066, above the Black Lake rd. 112 ca. 1/3 mi northeast of Rock Cr., *Artemisia tridentata/Carex geyeri-Potentilla glandulosa* community, 7,010', 8/31/83.

Agropyron caninum (L.) Beauv. ssp. *majis* (Vasey) Hitchc. var. undet., Bearded Wheatgrass.

Baird 9/8/71, Council R.D., dry, open slope below Horse Mt. Lookout, 5,800', 9/8/71.

Brewer 116, Council R.D., Sheep Rock, sec. 2, T. 21 N., R. 3 W., 6,500', 8/19/30.

C. Johnson Sight Records, Plot 7044, ca. 1½ mi north of Emerald Lake, along trail 214, 6,400', 8/19/83; and Plot 7067, near trail 217 in the head of Deep Cr., ca. 0.1 mi northwest of the Black Lake rd. 112, 7,150', 8/31/83.

Agropyron scribneri Vasey, Spreading Wheatgrass.

Uncommon, central Seven Devils, 7,100-8,400'.

Bingham and Miller 57, ID, open *Pinus albicaulis-Abies lasiocarpa* forest just east of the Bridge-Sheep Crs. divide at Goat Pass, 8,400', 7/24/79.

Plus 7 Sight Records by Bingham and Miller, trail 112 between the forks of Sheep Cr. to Horse Heaven Saddle, 7,100-8,000'.

Agropyron spicatum (Pursh) Scribn. and Smith var. *spicatum*, Bluebunch Wheatgrass.

Common, entire Seven Devils and Rapid River, 5,000-8,000'.

Baird 8/12/71, Council R.D., 1 mi north of Horse Mt. Lookout, 6,850', 8/12/71.

Baker 11998, ID, dry banks of wooded slope 5 mi west of Riggins (prob. along rd. 517 in Papoose Cr., ? elev.), 7/21/54.

Bingham and Miller 244, ID and WS, and 345, ID, in an *Artemisia tridentata* stand on a southwest-facing slope along the Old Boise Trail 192 just north of Stevens Saddle, 7,600', 8/27/80; and in grass-forb stand on rocky south-facing slope along trail 218 ca. ½ mi west of the summit between Black Lake and Joes Gap, 7,600', 7/18/81; respectively.

*Christ 8608, ?NY, high, open mountainside, Smith Mt., 8/8/37.

Plus 26 Sight Records by Bingham and Miller, Henderson, C. Johnson, Steele, and Tisdale, Big Canyon Saddle to Huntley Gulch, 5,000-8,000'.

Agrostis exarata Trin. ssp. *minor* (Hook.) Hitchc., the blunter- and shorter-glumed subspecies of Spike Bentgrass.

Scarce, southern Seven Devils, 5,000-6,500' +.

Baker 11324, ID, moist soil, edge of spring, 6 mi north of Cuprum (prob. along rd. 106 near Lockwood Saddle), 9/3/53.

?*Agrostis rossiae* Vasey, Ross' Bentgrass (but well outside its Yellowstone National Park range, often confused with *A. variabilis*).

*Christ 8656, ?NY, high ridges near Black Lake, 8/8/37.

Agrostis scabra Willd., Winter Bentgrass.

Occasional, central Seven Devils, 7,200-7,600'.

Bingham and Miller 435, ID and WS, under high waterline on the shore of Quad Lake, 7,200', 8/14/81.

Kruckeberg 3206, WS and WTU, just below Dry Diggins Lookout, 8/1/52.

Plus 2 lake-bank Sight Records by Bingham and Miller, shores of Baldy Lake, 7,200', and shores of Horse Lake, 7,200'.

Agrostis thurberiana A. S. Hitchc., Thurber Bentgrass.

Scarce, central Seven Devils, 7,500' ±.

St. John and Mullen 8583, WS, marshy shore of pond (vernal ponds along trail 123 between Basin and Gem Lakes?), Dry Diggins, 8,000', 7/25/27.

Agrostis variabilis Rydb., Variant Bentgrass.

Scarce, central to southern Seven Devils, 6,800-8,000'.

Baker 11305 & 12079, ID, moist shaded slope of Sheep Rock, 9/3/53; and dry rocky banks below Heavens Gate, 7/21/54; respectively.

Arrhenatherum elatius (L.) Presl, Oatgrass (European introduction).

Scarce, lower, central-eastern Seven Devils, 5,000' ±.

Baker 12158, thicket, Wildhorse Saddle, White Bird Ridge (prob. along rd. 624), 7/27/54.

Bromus brizaeformis Fisch. and Mey., Rattlesnake Grass (European introduction).

Uncommon, lower northern and central Seven Devils and Rapid River, 5,000-5,900'.

Baird 7/15/71, Council R.D., upper part of Kleinschmidt Grade, 5,000', 7/15/71.

Baker 11988, ID, Papoose Cr. 4 mi west of Riggins (prob. along rd. 517), ? elev., 7/21/54.

Bingham 554, ID, open grass-forb-sedge stand on ridgetop ca. 150' east of Grave Point Lookout tower, 5,630', 7/21/82.

Plus 6 Sight Records by Bingham and Miller, C. Johnson and Tisdale, Cow Cr. Saddle to McGaffee Cow Camp, 5,200-5,900'.

Bromus carinatus Hook. and Arnott var. *carinatus*, California Brome.

Abundant, mostly northern and central Seven Devils, 5,200-8,000'.

Baker 12012, ID, Papoose Cr. 4 mi west of Riggins (prob. along rd. 517), 7/21/54.

Bingham and Miller 154 & 243, ID and WS, southeast-facing slope in sedge-forb meadow opening in forest, along the Old Boise Trail just northeast of Hanson Cr., 6,800', 7/17/80; and southwest-facing sagebrush-grass stand ca. 0.2 mi northwest of Stevens Saddle along trail 192, 7,600', 8/27/80; respectively.

*Christ 12709, ?NY, open mountainside along the Sheep Cr. trail, 7/17/41.

Henderson 3861, ID, Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7/6/77.

Hermann 12035, NA, WS, vicinity of Cold Springs Lookout, 6,900', 8/6/55.

?*Nelson and Nelson 3006, RM, top of He Devil, 8/10-15/38. (Prob. too high for this taxon, not collected or seen atop He Devil by St. John or Bingham and Miller).

Plus 36 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Bromus inermis Leys. ssp. *inermis*, Smooth Brome (European introduction).

Scarce, central Seven Devils, 6,800' ±.

Bingham and Miller 424, ID and WS, open gravelly hillside with grass-forb stand on a southeast-facing slope ca. ½ mi down trail 112 along the north Fk. of Little Granite Cr. from Hibbs Cow Camp, 6,800', 8/11/81.

Bromus inermis Leys. ssp. *pumpellianus* (Scribner) Wagnon var. *pumpellianus*, the glabrous-glumed variety of Pumpelly Brome, a North American native plant.

Scarce, southern Seven Devils, 7,200' ±.

*Christ 8646, ?NY, in a *Abies lasiocarpa* timber surrounding Black Lake, 8/8/37.

Bromus inermis Leys. ssp. and var. undet.

Bingham and Miller Sight Record, in the talus slopes along the Old Boise Trail 101 ca. 0.1 mi east of Horse Heaven Saddle at the jct. of trails 101, 114, and 124, 7,700', 8/18/81.

Bromus japonicus Thunb., Japanese Brome-grass (Eurasian introduction).

Scarce, lower northern and southern Seven Devils, 5,000-5,200'.

Baird 7/15/71, Council R.D., upper part of Kleinschmidt Grade, 5,000', 7/15/71.

Tisdale Sight Record, Plotsites 73 and 74, vicinity of Low Saddle, 5,200', 7/13/78.

Bromus suksdorfii Vasey, Suksdorf's Brome-grass.

Scarce, southern Seven Devils, 7,000' ±.

Baker 11313, ID, grassy, open meadow, Kinney Point, 9/3/53.

Bromus tectorum L., Cheat Grass (Eurasian introduction).

Uncommon, entire lower Seven Devils and Rapid River, 5,000-6,600'.

Bingham and Miller 576, ID and WS, in the roadbed of rd. 517 ca. ¼ mi up the rd. from its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82; also Sight Records, west of Cold Springs Cow Camp, at Sawpit Saddle, and along Rapid River, 5,000-6,600'.

Bromus vulgaris (Hook.) Shear var. *vulgaris*, Columbia Brome.

Uncommon, entire Seven Devils, 5,000-7,000'.

Baird 8/6/71 & 8/18/71, Council R.D., ½ way through the Landore-Cuprum rd. (105), 5,000', 8/6/71; and in timber along rd. 2 mi south of Landore, 5,500', 8/18/71; respectively.

Baker 12259, ID, moist woods along Shingle Cr. (prob. the north fork along rd. 517), 7/31/54.

*Christ 12699, ?NY, timbered hillside along the Sheep Cr. trail, 7/17/41.

Plus 6 Sight Records by C. Johnson and Steele, Motthorn Saddle to Hanson Cr., 5,100-6,800'.

?*Calamagrostis canadensis* (Michx.) Beauv., Bluejoint Reedgrass.

Baird 8/18/71, Council R.D., in timber along rd. (105) south of Landore, 5,000', 8/18/71 (but geog. range normally is west Washington, Olympic and Cascade Mts., and north Sierra Nevada of Calif.).

Calamagrostis rubescens Buckl., Pinegrass.

Common, entire Seven Devils, 5,000-7,600'.

Baird 8/18/71, Council R.D., in timber along rd. 105 2 mi south of Landore, 5,500', 8/18/71.

Baker 12299 & 11334, ID, grassy north slopes of Kinney Point, 9/3/53; and grassy, wooded knoll 6 mi north of Cuprum (prob. along rd. 106), 9/3/53; respectively.

*Christ 8604, ?NY, timbered mountainside, Placer Basin (prob. along rd. 112), 7/7/37.

Plus 24 Sight Records by Bingham and Miller, C. Johnson, and Steele, Wild Horse Butte to Huntley Gulch, 5,000-7,600'.

Cinna latifolia (Trevir.) Griseb., Woodreed.

Scarce, southern Seven Devils and upper Rapid River, 7,500' ±.

Brewer 80, Council R.D., Paradise Cr., sec. 15, T. 22 N., R. 3 W., 4,500', 8/29/29 (but the Paradise Cr. location and elev. would place the collection in lower Paradise Cr. about ½ mi west of the main Rapid River in sec. 21 or 28, T. 22 N., R. 1 W.).

*Christ 8625, ?NY, springy places on mountainside, Black Lake, 7/7/37.

Dactylis glomerata L., Orchard-grass (Eurasian introduction).

Scarce, central Seven Devils, 5,700' ±.

C. Johnson Sight Record, Plot 7033, east of trail 110 on the Log-Old Timer Crs. ridge ca. 1 mi northeast of the jct. of trails 110 and the east fork of Sheep Cr. trail 58, 5,720', 8/13/83.

Danthonia intermedia Vasey, Timber Oatgrass.

Frequent, northern and central Seven Devils, 6,600-8,000'.

Baird 9/3/71, Council R.D., open flat on ridge by Kinney Point, 7,500', 9/3/71.

Bingham and Miller 227, ID and WS, in the large grass-sedge-forb meadow comprising the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. Line ca. ¼ mi south of the Horse Heaven Lookout cabin, 8,000', 8/25/80.

*Hermann 12037, ?US, vicinity of Cold Springs Lookout, 6,900', 7/6/55.

C. Johnson 8/10/83, BKR 2476, Plot 7011, ca. 200' west of trail 101 in the Horse Heaven Lookout pasture, *Festuca idahoensis-Carex hoodii* h.t., 8,040', 8/10/83.

Tisdale 7/11/79, IDF 81103, mountain grassland 1½ mi west of Cold Springs Lookout, 6,600', 7/11/79.

Plus 7 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, vicinities of Horse Heaven Saddle, Cold Springs Cow Camp, Horse Heaven Lookout pasture, Dry Diggins Ridge, the Narrows, along the Old Boise Trail 101, Fire Camp Saddle, Bald Mt., and Seven Devils Guard Station, 6,600-7,800'.

Danthonia spicata (L.) Beauv., Common Wild Oatgrass.

Scarce, northern Seven Devils, 5,200' ±.

Tisdale Sight Record, Plots 73 and 74, vicinity of Low Saddle, 5,200', 7/13/78.

Danthonia unispicata (Thurb.) Munro, Onespike Oatgrass.

Scarce, central Seven Devils, 6,500' ±.

C. Johnson Sight Record, Plot 7034, west of trail 110 just west of the Old Timer Mine and cabin, 6,470', 8/13/83.

Deschampsia caespitosa (L.) Beauv. var. *caespitosa*, Tufted Hairgrass.

Scarce, southern Seven Devils, 6,800' ±.

C. Johnson 8/31/83 (2 colls.), BKR 2492 and 2493, both from Plot 7069, west of the Deep Cr. trail 219 ca. ½ mi west of the Black Lake rd. 112 at High Dive in the head of Deep Cr., 6,760', 8/31/83.

Deschampsia elongata (Hook.) Munro, Slender Hairgrass.

Scarce, southern Seven Devils, 6,500-7,200'.

Baker 11331, ID, moist ground about spring 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

*Christ 8638, ?NY, shore of Black Lake, 8/8/37.

Elymus cinereus Scrib. and Merrill var. *cinereus*, Giant Wildrye.

Occasional, southern Seven Devils and Rapid River, 5,000-7,000'.

Brewer 119, Council R.D., Helena Ranger Station, sec. 12, T. 22 (?21) N., R. 3 W., 7,000' (apparently at Old Helena near the Peacock Mines), 8/19/30.

Plus 2 Sight Records by Bingham and Miller; lower and west fork of the Rapid River, 2,300-2,700'.

Elymus glaucus Buckl., var. undet., Western Rye-grass.

Uncommon, central and southern Seven Devils, 7,000-7,800'.

*Christ 8701, ?NY, lower slopes above Black Lake, 8/8/37.

C. Johnson Sight Records: Plot 7021, along trail 124 ca. 1 mi south of Hibbs Cow Camp, 7,050', 8/11/83; Plot 7024, along trail 112 just below Hibbs Cow Camp, 7,060', 8/11/83; Plot 7044, east of trail 214 ca. 1½ mi north of Emerald Lake, 6,400', 8/19/83; and Plot 7065, along trail 214 ca. ¼ mi west of the south end of Black Lake, 7,460', 8/30/83.

Festuca idahoensis Elmer var. *idahoensis*, Idaho Fescue.

Abundant, entire Seven Devils and Rapid River, 5,000-8,500'.

Baird 8/15/71, Council R.D., Horse Heaven, 7,500', 8/15/71.

Bingham and Miller 205 & 226, ID and WS, open and exposed, rocky ridgetop in the immediate vicinity of the Horse Heaven Lookout cabin, 8,200', 8/25/80; and open subalpine grass-sedge-forb meadow in the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. Line, 8,000', 8/25/80; respectively.

Brewer 29, IDF, coarse gravel, open grassland, Jackley Mt., 8,500', 7/23/28.

*Christ 12570, ?NY, open west slopes, Heavens Gate, 7/12/41.

Henderson 3859, ID, near the Little Granite-Three Crs. divide, ca. ¼ mi southwest of Hibbs Cow Camp, 7/6/77.

*Hermann 12036, ?US, vicinity of Cold Springs Lookout, 6,900', 8/6/55.

Kruckeberg 3209, WS, WTU, steep slopes at end of road from Riggins (rd. 517 at Windy Saddle), 7,500', 8/1/52.

St. John and Mullen 8511, WS, cliff crevice, Dry Diggins, 8,000', 7/21/27.

Wellner 1681, ID, peak at north end of Pollock Mt., 8,050', 8/6/79.

Plus 52 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Tisdale (1979) described a *Festuca idahoensis/Koeleria cristata* habitat type occupying much of the 5,000-6,000' grasslands of the lower Seven Devils. Later (1983) he also described a *Carex hoodii/Festuca idahoensis* habitat type characteristic of much of the mid-elev. Seven Devils grasslands at 6,000-8,000' elev.

Festuca occidentalis Hook., Western Fescue.

Occasional, northern and central Seven Devils, 5,000-5,600'.

C. Johnson Sight Records: Plot 791, above rd. 2060 ca. ¼ mi west of Lost Valley Cr., 5,100', 6/29/82; Plot 792, above rd. 2060 just northeast of Lost Valley Cr., 5,220', 6/29/82; Plot 7030, along trail 110 on the Sawyer-Bear Trap Crs. ridge ca. ¼ mi east of the 6,122' hill, 5,600', 8/13/83; and Plot 7032, along trail 110 ca. 1/3 mi northeast of its jct. with the east fork of Sheep Cr. trail 58, 5,200', 8/13/83.

Festuca rubra L. var. *rubra*, Red Fescue.
Scarce, central Seven Devils, 6,500-7,600'.
Baker 12021, ID, open alpine slopes, Seven Devils Camp, 7/21/54.
*Christ 12624, ?NY, timbered mountainside with Douglas-fir on trail (prob. 124) to Baldy Lake, 7/15/41.

Koeleria cristata Pers., Prairie Junegrass.
Common, entire Seven Devils, 5,000-7,800'.
Bingham 268, ID and WS, northeast-facing open grassland in the *Festuca idahoensis-Koeleria cristata* h.t., ca. ¼ mi north of Sawpit Saddle along the low ridge near the viewpoint over Temperance Cr. and Suicide Point, beyond the end of rd. 2060, 5,050', 7/8/81.
*Christ 8602, ?NY, timbered mountainside, Placer Basin, 8/8/37.
C. Johnson 8/12/83, BKR 2563, Plot 7027, east of the Dry Diggins Ridge trail 140 at the drop-off ca. 2¼ mi north of the Iron Phone at the jct. of trails 140, 112, and 57, *Festuca idahoensis-Antennaria* community, 7,370', 8/12/83.
Plus 17 Sight Records by Bingham and Miller, C. Johnson and Tisdale, Low Saddle and Cold Springs Lookout site to Hibbs Cow Camp, 5,200-7,800'.

Melica bulbosa Geyer var. *bulbosa*, Oniongrass.
Frequent, entire Seven Devils, 5,200-8,000'.
Baker 12017, ID, open alpine slopes, Seven Devils Camp, 7/21/54.
*Christ 8607 & 12523, ?NY, high, open mountainside, Smith Mt., 7/8/37; and open east slopes, Heavens Gate, 7/12/41; respectively.
Christ 12471, WS, on cliffs, Seven Devils Ridge, 7/11/41.
Henderson 3857, ID, Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7,600', 7/6/77.
Kruckeberg 3210, WS, WTU, metamorphic outcrops on steep slopes at end of rd. from Riggins (rd. 517 at Windy Saddle), 7,500', 8/1/52.
Lewis 2273, BOIS, OGDF, Steele Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72.
St. John and Mullen 8518, WS, grassy slopes near Hibbs Cow Camp, 7/21/27.
Plus 3 Sight Records by C. Johnson, and Steele, along rd. 2060 near Kirkwood Cr., and along rd. 002 near the Bear-Indian Crs. divide.

Melica spectabilis Scribn., Showy Oniongrass.
Uncommon, entire Seven Devils, 6,700-8,100'.
C. Johnson Sight Records: Plot 7012, east of trail 124 in Haas Flat ca. ½ mi north of Horse Heaven Saddle, 8,070', 8/10/83; Plot 7059, west of Six Lake Basin trail 218 ca. 0.1 mi north of the Black Lake to Joes Gap Summit northwest of Pyramid Peak, 8,020', 8/30/83; Plot 7066, west of the Black Lake rd. 112 ca. 1/3 mi northeast of Rock Cr., 7,010', 8/31/83; Plot 7067, below trail 217 in the head of Deep Cr. ca. 0.1 mi northwest of the Black Lake rd. 112, 7,150', 8/31/83; and Plot 7068, below trail 217 in the head of Deep Cr. ca. ¼ mi northwest of the Black Lake rd. 112, 6,960', 8/31/83.
Tisdale 7/12/79, IDF 80175, 400 yds. north of the site of Cold Springs Lookout, 6,700', 7/12/79.

Melica subulata (Griseb.) Scribn. var. *subulata*, Alaska Oniongrass.
Scarce, northern Seven Devils, 5,100' ±.
C. Johnson 6/29/82, BKR 2238, Plot 791, above rd. 2060 ca. ¼ mi west of Lost Valley Cr., 5,100', 6/29/82.

Melica subulata (Griseb.) Scribn. var. undet., Alaska Oniongrass.
Occasional, central Seven Devils, 5,800-6,800'.

*Christ 12633, ?NY, Douglas-fir timbered mountainside on trail to Baldy Lake (prob. trail 124), 7/15/41.

C. Johnson Sight Records: Plot 7019, ca. 1¼ mi west of Echo Lake on trail 124, 6,610', 8/11/83; and Plot 7029, along trail 110 on the Sheep-Bills Crs. divide ca. ½ mi north of trail 140, 5,800', 8/13/83.

Muhlenbergia filiformis (Thurb.) Rydb., Slender Muhlenbergia.

Scarce, southern Seven Devils, 8,000' ±.

*Christ 8655, ?NY, high ridges near Black Lake, 8/8/37.

Oryzopsis hendersonii Vasey, Henderson's Ricegrass.

Occasional, central Seven Devils, 5,600-8,500'.

*Christ 8610 & 12617, ?NY, rocky slope, Smith Mt., 8/8/37; and promontory jutting into Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41; respectively.

*Kruckeberg 3201, ?WTU, in flats on high promontory overlooking Hells Canyon ½ mi east of Dry Diggins Lookout, 8/1/52.

St. John and Mullen 8560, WS, rock ledge on He Devil Mt., 8,500', 7/24/27.

Phleum alpinum L., Mountain Timothy.

Scarce, central Seven Devils, 8,000' ±.

C. Johnson Sight Record, Plot 7037, west of the Old Boise Trail 101 ca. ½ mi southwest of Papoose Lake, 7,980', 8/14/83.

Phleum pratense L., Timothy (Eurasian introduction).

Uncommon, northern and central Seven Devils and Rapid River, 5,000-7,200'.

Bingham and Miller 391, ID, south-facing, open, rocky slope in an open brushfield of an old burn, ca. ½ mi up the Cannon Lake trail from the Old Boise Trail 101, 6,800', 7/27/81.

Bingham and Miller Sight Records: along Bernard Lakes trail 56 just north of its jct. with trail 112, 7,600', 8/11/81; along the north fork Bernard Cr. trail 110 just east of McGaffee Cow Camp, 5,800', 8/12/81; along the north fork Little Granite Cr. trail 112 ca. 1/3 mi south of Hibbs Cow Camp, 7,200', 8/11/81; along the lower Rapid River trail 113 at the Circle C Fish Hatchery trailhead gate, 2,200', 6/8/82; along rd. 517 ca. ¼ mi above the 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82; and at Sawpit Saddle, 5,050', 7/8/81.

Poa bolanderi Vasey, Bolander's Bluegrass.

Occasional, central and southern Seven Devils, 7,200-7,500' ±.

Baker 12274, ID, moist ground along stream to the west of Heavens Gate (possibly near the stock-watering spring), 7/31/54.

Bingham and Miller 143, ID, east-facing, open, rocky slope at the edge of a boulderfield, sedge-forb meadow in opening in *Abies lasiocarpa, Picea engelmannii, Pinus albicaulis* forest, along the south side of the bottom of Dog Cr. ca. 3/5 mi below the Lake, 7,500', 7/16/80.

*Christ 8624, ?NY, roadside, Black Lake, 8/8/37.

Poa bulbosa L., Bulbous Bluegrass (European introduction).

Occasional, northern Seven Devils and Rapid River, 5,000-6,800'.

Bingham and Miller Sight Records: along trail 104 at Big Canyon Saddle, 5,000', 6/11/82; along the Old Boise Trail 101 ca. ¼ mi south of its rd. 1819 trailhead southeast of Cold Springs Lookout, 6,800', 7/9/81; at the Circle C State Fish Hatchery trail 113 trailhead gate at the southwest end of the Hatchery, 2,200', 6/8/82; and along the west fork of the Rapid River trail 113 ca. ½ mi west of the main forks in sec. 26, 2,900', 6/9/82.

Poa cusickii Vasey var. *epilis* (Scribn.) Hitchc., Skyline Bluegrass.

Uncommon, central and southern Seven Devils, 7,600-8,100'.

Bingham and Miller 336, ID, southeast-facing, open, bedrock area in an open *Pinus albicaulis, Abies lasiocarpa* stand, just south of Purgatory Saddle, 7,900', 7/17/81.

*Christ 8668, ?NY, high slopes on Pyramid Peak, 8/8/37.

Christ 12498, ID, under cover in conifer grove, Seven Devils Camp, 7/12/41.

C. Johnson 8/10/83 & 8/14/83, BKR 2477 and 2483, Plot 7012, above trail 124 on Haas Flat ca. ½ mi north of Horse Heaven Saddle, 8,070', 8/10/83; and Plot 7011, west of the Old Boise Trail 101 in the Horse Heaven Lookout pasture, 8,040', 8/10/83; respectively.

Plus 2 Sight Records by Bingham and Miller and C. Johnson.

Poa cusickii Vasey var. undet., Cusick's or Skyline Bluegrass.

Tisdale 7/15/78, IDF 79037, mountain grassland, Seven Devils Guard Station pasture, 7,300', 7/15/78.

Poa nervosa (Hook.) Vasey var. *wheeleri* (Vasey) Hitchc., Wheeler's Bluegrass.

Common, entire Seven Devils, 5,100-7,600'.

Bingham 323, ID and WS, lakeshore at edge of moderately dense *Abies lasiocarpa, Picea engelmannii, Pinus contorta* forest, northwest shore of Black Lake, 7,200', 7/17/81.

Christ 12568, ID, open west slopes of Heavens Gate, 7/12/41.

Henderson 3862, ID, Little Granite - Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7/6/77.

Lewis 2274, BOIS, OGDF, near Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730', 6/12/72.

Tisdale 7/13/78, 7/14/78, & 7/11/79, IDF 79036, 79040, and 80161, vicinity of Cold Springs Cow Camp, 6,700', 7/13/78; vicinity of Seven Devils Guard Station pasture, 7,400', 7/14/78; and 400 yd. north of Cold Springs Lookout, 6,500', 7/11/79; respectively.

Plus 16 Sight Records by C. Johnson and Steele.

Poa nevadensis Vasey, Nevada Bluegrass.

Scarce, southern Seven Devils, 5,100-5,700'.

Lewis 2275a, BOIS, Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,730' (actually stand is at 5,130' and, 6/12/72 Lewis was collecting for Steele, see below).

Steele Sight Record, Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,130', 6/12/72.

Poa pratensis L., Kentucky Bluegrass.

Scarce, central Seven Devils and Rapid River, 6,500' ±.

Bingham and Miller Sight Record, at the trail 113 trailhead gate at the southwest end of the Circle C State Fish Hatchery, in the trail, 2,200', 6/8/82.

C. Johnson Sight Record, Plot 7034, just west of the Old Timer Mine and cabin along trail 110, 6,470', 8/13/83.

Poa secunda Presl (incl. *P. gracillima* Vasey and *Poa sandbergii* Vasey), Sandberg's Bluegrass.

Common, entire Seven Devils and west fork Rapid River, 5,000-9,400'.

Baker 12054 & 12278, ID, open alpine slopes, Seven Devils Camp, 7/21/54; and open, gravelly slopes west of Seven Devils Camp, 7/31/54; respectively.

Bingham and Miller 49, 60, & 99, ID, in bedrock crevices ca. 0.2 mi south of the Tower-of-Babel--She Devil Mt. saddle on the north end of She Devil Mt., 9,050', 7/23/79; in crevices on cliffs just on the Mirror Lake side of the Bridge-Sheep Crs. divide at Goat Pass, ca. 0.2 mi west of Mirror Lake, 8,400', 7/24/79; and ca. 50' south and 25' below the summit of He Devil Mt. on a bedrock ledge, 9,370', 7/26/79; respectively.

*Christ 12462 & 12569, ?NY, cliff crevices, Seven Devils Ridge, 7/11/41; and open west slopes, Heavens Gate, 7/12/41; respectively.

Plus 29 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Big Canyon Saddle to Lockwood Saddle, 5,050-8,100'.

Puccinellia pauciflora (Presl) Munz var. *holmii* (Beal) Hitchc., Weak Alkaligrass.

Scarce, central and southern Seven Devils, 7,200' ±.

Bingham and Miller 444, ID, southeast shore of Ruth Lake, 7,200', 8/17/81.

*Christ 8637, ?NY, colony on shore of Black Lake, 8/8/37.

Sitanion hystrix (Nutt.) J. G. Smith var. *brevifolium* (J. G. Smith) Hitchc., Small-leaved Squirrel-tail.

Uncommon, entire Seven Devils, 5,000-9,000'.

Baker 12020, ID, Seven Devils Camp, 7/21/54.

Bingham and Miller 204, ID and WS, northeast-facing, open, bedrock area with fine loam between rocks supporting a grass-sedge-forb stand, in an open *Abies lasiocarpa-Pinus albicaulis* forest in the immediate vicinity of Horse Heaven Lookout cabin, 8,200', 8/25/80.

*Christ 8711, 12478, & 12705, ?NY, high ridges and rocky exposures near Black Lake, 8/8/38; slopes on crest of Seven Devils Ridge, 7/11/41; and slide rock in west slopes along the Sheep Cr. trail (112), 7/17/41; respectively.

*Nelson and Nelson 3007, ?RM, top of He Devil, 8/10-15/38.

Plus 2 Sight Records by Bingham and Miller, Sawpit Saddle and Dry Diggins Ridge trail 140, 5,000-7,300'.

Sitanion hystrix (Nutt.) J. G. Smith var. *hystrix*, Squirrel-tail.

Frequent, central and southern Seven Devils, 7,000-8,000'.

Ten C. Johnson Sight Records: shores of Haas Lake, 7,240', 8/9/83; Horse Heaven Lookout pasture, 8,040', 8/10/83; ca. 0.1 mi west of Potato Hill, 7,730', 8/10/83; 1 mi south of Hibbs Cow Camp, 7,050', 8/11/83; along trail 101 ca. 1/3 mi south of The Narrows, 7,660', 8/14/83; ca. 0.1 mi northwest of Stevens Saddle, 7,710', 8/20/83; 2d lake of Six Lake Basin going west on trail 217, 7,360', 8/30/83; Horse Pasture Basin, 7,620', 8/30/83; 1/3 mi northeast of Rock Cr. along rd. 112, 7,010', 8/31/83; and head of Deep Cr. ca. ¼ mi northwest of rd. 112 in High Dive cirque, 7,150', 8/31/83.

Sitanion hystrix (Nutt.) J. G. Smith var. undet., Squirrel-tail.

Brewer 111, IDF, sec. 36, T. 22 N., R. 2 W. (prob. along trail 191 2+ mi east of Black Lake), 6,500', 8/18/30.

Stipa lettermannii Vasey, Letterman's Needlegrass.

Scarce, central and southern Seven Devils, 7,300-7,600'.

*Christ 8705, ?NY, on slopes above Black Lake, 8/8/37.

Kruckeberg 3202, WTU, in flats on high promontory overlooking Hells Canyon of Snake River ½ mi east of Dry Diggins Lookout, 8/1/52.

Stipa occidentalis Thurb. var. *minor* (Vasey) Hitchc., the variety of Western Needlegrass lacking long lemma-tip hairs but with glabrous and short awns (syn. *S. columbiana* Macoun v. *columbiana*, Columbia Needlegrass).

Uncommon, northern and central Seven Devils, 6,800-8,200'.

C. Johnson Sight Records: Plot 7009, above trail 101 southeast of Haas Lake overlooking Mill Cr. ca. 0.8 mi east of Horse Heaven Saddle, 7,350', 8/9/83; Plot 7012, above trail 124 and 150' below the rim overlooking Haas Basin on Haas Flat ca. ½ mi north of Horse Heaven Saddle, 8,070', 8/10/83; Plot 7051, along trail 192 ca. ¼ mi east of Deb's Corral at the jct. of trails 189 and 192, 7,000', 8/20/83; Plot 7071, east of the Old Boise Trail 101 in the head of Kessler Cr., ca. 2 mi south of the rd. 1819 trailhead southeast of Cold Springs Lookout, 6,780', 9/1/83; and Plot 7075, ca. 0.1 mi southwest of Heavens Gate Lookout, 8,170', 9/2/83.

Stipa occidentalis Thurb. var. *nelsonii* (Scribn.) Hitchc., the variety of Western Needlegrass without long lemma-tip hairs but with glabrous and long awns (syn. *S. columbiana* Macoun var. *nelsonii* [Scribn.] St. John, Nelson's variety of Columbia Needlegrass).

Occasional, central Seven Devils, 8,000-8,200'.

Bingham and Miller 209 & 228, ID and WS, moderately dry, exposed, subalpine ridgetop with a sedge-forb stand in an open *Abies lasiocarpa-Pinus albicaulis* forest immediately northeast of the Horse Heaven Lookout cabin, 8,200', 8/25/80; and gently south-facing, open, subalpine meadow with a grass-sedge-forb stand in the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. Line, 8,000', 8/25/80; respectively.

St. John and Mullen 8521, WS, rocky crest of Dry Diggins, 8,000', 7/22/27.

Stipa occidentalis Thurb. var. *occidentalis*, the variety of Western Needlegrass with semi-plumose awns.

Frequent, central and southern Seven Devils, 7,000-8,000'.

11 C. Johnson Sight Records: Six Lakes Basin, Horse Pasture Basin head of Deep Cr. northwest of rd. 112, Horse Heaven Lookout pasture, vicinity of Potato Hill, along trail 112 south of Hibbs Cow Camp, at the drop-off on Dry Diggins Ridge, along trail 101 south of The Narrows, and along trail 101 southwest of Papoose Lake, Stevens Saddle, and head of Deep Cr., 6,960-8,040'.

Stipa occidentalis Thurb. var. intermediate between var. *minor* (Vasey) Hitchc. and var. *occidentalis*, Western Needlegrass.

Scarce, southern Seven Devils, 7,000' ±.

C. Johnson Sight Record, Plot 7066, above the Black Lake rd. 112 ca. 1/3 mi northeast of Rock Cr., 7,010', 8/31/83.

Stipa occidentalis Thurb. var. undet., Western Needlegrass.

Bingham and Miller Sight Records: along trail 101 northwest of Papoose Lake, Dry Diggins Lookout, along Dry Diggins Ridge trail 140 2 mi north of the Iron Phone, along trail 112 1/3 mi south of Hibbs Cow Camp, along trail 101 ½ mi southwest of Horse Heaven Cr., along trail 218 just west of the summit between Black Lake and Joes Gap, and along trail 124 in the switchbacks at the head of the south fork of Devils Farm Cr., 7,000-8,000'.

Brewer 120, Council R.D., Jackley Guard Station (apparently near the Lookout), sec. 13, T. 22 N., R. 3 (?2) W., 7,000', 8/17/38.

Steele Sight Records: Stand 72-Pa-25 and 26, Bear-Cuprum rd. 002, above Huntley Gulch and at the Bear-Indian Crs. divide, 5,100-5,130', 6/12/72.

Tisdale Sight Records: vicinities of Cold Springs Cow Camp, Cold Springs Lookout, Bald Mt., and Seven Devils Guard Station, 6,600-7,800', 7/11-17/79.

Trisetum canescens Buckl., Tall Trisetum.

Occasional, central Seven Devils, 5,200-5,700'.

C. Johnson Sight Records: Plot 7030, below trail 110 on the Sawyer-Bear Trap Crs. ridge at the bottom of the 1st switchback going east from McGaffee Cow Camp, 5,600', 8/13/83; Plot 7032, above trail 110 ca. ½ mi northeast of its jct. with trail 58, 5,200', 8/13/83; and Plot 7033, below trail 110 on the Log Cr. side of the Log-Old Timer Crs. ridge ca. 1 mi above the jct. with 58, 5,720', 8/13/83.

Trisetum spicatum (L.) Richter, Downy Oatgrass.

Common, central and southern Seven Devils, 5,100-8,400'.

Baker 12026 & 12075, ID, open alpine slopes, Seven Devils Camp, 7/21/54; and dry, gravelly soil on rocky point above 7 Devils Guard Station, 7/21/54; respectively.

Bingham and Miller 59 & 208 and Bingham 337, ID, and Bingham and Miller 155, ID and WS, southeast-facing bedrock cliff crevices immediately southeast of Goat Pass on the Mirror Lake side of the Bridge-Sheep Creeks divide, 8,400', 7/29/79; moderately dry, exposed and open rocky ridgetop with a sedge-forb meadow in a large forest opening, immediately northeast of the Horse Heaven Lookout cabin, 8,200', 8/25/80; open bedrock area with an *Abies lasiocarpa-Pinus albicaulis* stand, along trail 214 just south of Purgatory Saddle, 7,900', 7/17/81; and ca. 0.1 mi northeast of Hanson Cr. in a large forest opening on a gentle southeast-facing slope with a sedge-forb meadow just below the Old Boise Trail 101, 6,800', 7/17/80; respectively.

*Christ 8669 & 12563, ?NY, rocky ridge on Pyramid Peak, 8/8/37; and open west slopes, Heavens Gate, 7/12/41; respectively.

Henderson 3860, ID, near the Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7/6/77.

C. Johnson 8/30/83, BKR 2581, Plot 7064, east of trail 217 in

Horse Pasture Basin ca. ¼ mi southeast of Joes Gap, fire succession community, 7,620', 8/30/83.

*Nelson and Nelson 3005, ?RM, top of He Devil, 8/10-15/38.

Sharp and McKendrick 9/2/65, ID 83013, openings in woods, Heavens Gate Lookout, 9/2/65.

Wellner 1677, ID, ca. ¼ mi north of the lookout on Pollock Mt., 8,050', 8/6/78.

Plus 18 Sight Records by Bingham and Miller and C. Johnson.

Polemoniaceae

Collomia debilis (Wats.) Greene var. *debilis*, Alpine Collomia.

Uncommon, central and southern Seven Devils, 7,100-8,800'.

Bingham and Miller 63, ID, open, loose, small-rock talus on the steep talus slope between Goat Pass and Mirror Lake, 8,300', 7/24/79.

*Christ 8666, ?NY, in sand and rockslides, Pyramid Peak (south-southwest of Black Lake), 8/8/37.

Henderson 3853, ID, talus along the south side of trail 112 ca. ½ mi eastward from the Windy Saddle trailhead, 7/7/77.

St. John and Mullen 8566, WS, loose rock near summit of He Devil Mt., 8,800', 7/24/27.

Plus 1 Sight Record by Bingham and Miller.

Collomia grandiflora Dougl., Large-flowered Collomia.

Occasional (mostly at lower elevs.), central Seven Devils and Rapid River, 5,000' minus.

Baker 11989, ID, dry rocky banks along Papoose Cr., 4 mi west of Riggins, ? elev., 7/21/54.

Bingham and Miller 487, ID and WS, open south-facing slope with an *Agropyron spicatum*/forb stand along the lower Rapid River ca. 1¼ mi above the Circle C State Fish Hatchery, 2,400', 6/8/82.

Plus 1 Sight Record by Bingham and Miller, in west fork Rapid River just west of the main forks, 2,800', 6/8/82.

Collomia linearis Nutt., Narrow-leaf Collomia.

Common, entire Seven Devils, 5,000-8,000'.

Baker 12068, ID, rocky point above Seven Devils Guard Station, 7/21/54.

Bingham and Miller 145, ID and WS, open, east-facing, sedge-forb meadow in the bottom of Dog Cr. ca. 3/5 mi below Dog Lake, 7,500', 7/16/80.

Plus 23 Sight Records by Bingham and Miller, C. Johnson, Steele, and Tisdale, Big Canyon Saddle to Black Lake, 5,000-8,100'.

Collomia tinctoria Kell., Yellow-staining Collomia.

Scarce, central Seven Devils, 7,000-8,000'.

Christ 12675, ID and WS, sliderock, Sheep Cr. trail, 7/17/41.

Gilia aggregata (Pursh) Spreng. var. *aggregata*, Scarlet Gilia.

Frequent, entire Seven Devils and Rapid River, 5,000-7,800'.

Baker 12051, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 103, ID, and 201, ID and WS, open, rocky, south-facing slope above the Seven Devils Campground rd. ca. ¼ mi southwest of Windy Saddle, 7,600', 7/26/79 (this population includes a very small proportion of forms with light cream-yellow, flaring corollas considered to be mutants, not the Rocky Mt. variety *attenuata* Gray); and sandy-gravelly, south-facing rocky slope with an open sedge-grass-forb stand, ca. ¼ mi east of Horse Heaven Saddle, 7,200', 8/24/80; respectively.

Pennell 20820, PH, rocky, ryolitic soil, Smith Mt. north of Bear, 7,500-7,700', 7/9/37.

Plus 12 Sight Records by Bingham and Miller, and C. Johnson, Camp Howard Triangulation Station to Black Lake, 6,050-7,800'.

Leptodactylon pungens (Torr.) Nutt., Leptodactylon.

Scarce, Rapid River only, 2,800' ±.

Bingham and Miller Sight Record, ca. ¼ mi up the west fork Rapid River trail 113 from the main forks in sec. 26, 2,800', 6/9/82.

Linanthastrum nuttallii (Gray) Ewan, Nuttall's Linanthastrum.

Frequent, central and southern Seven Devils, 6,700-8,500'.

Bingham and Miller 82 & 117, ID, south-facing, open and exposed cliff base along trail 123 ca. 1/8 mi west of Sheep Lake, 8,200', 7/25/79; and south-facing, open bedrock and talus slopes ca. 0.1 mi north of Hanson Cr. and 0.2 mi east of Lower Hanson Lake, 7,900', 7/15/80; respectively.

*Christ 8691, ?NY, crevices in high cliffs near Black Lake, 8/8/37.

Christ 12703, WS, sliderock in west slopes along Sheep Cr. trail (112), 7/17/41.

*Packard 345, ?WS, on moist, rocky soil along the Brundage Trail (112) between the forks of Sheep Cr., 6,000' (prob., nearer 6,800'), 6/30/37.

*Nelson and Nelson 3022, ?RM, Horse Heaven, 8/10-15/38.

St. John and Mullen 8538, WS, lava rockslide on He Devil Mt., 8,500', 7/23/27.

Wellner 1699, ID, slopes northeast and above Little Baldy Lake, 7,200', 8/22/78.

Plus 6 Sight Records by Bingham and Miller.

Linanthus harknessii (Curran) Greene, Harkness' Linanthus.

Scarce, central Seven Devils, 7,300' ±.

St. John and Mullen 8524, WS, gravelly slide, Dry Diggins, 8,000', 7/22/27.

Microsteris gracilis (Hook.) Greene var. *humilior* (Hook.) Cronq., the east Cascadian variety of Microsteris.

Uncommon, northern and north-central Seven Devils, 5,300-6,700'.

C. Johnson Sight Records: Plot 786, just north of Caribou Cr. ca. ½ mi down the creek from rd. 2060, 5,260', 6/27/82; Plot 793, just southwest of Grave Point Lookout, 5,550', 6/29/82; Plot 999, northwest of rd. 1819 southwest of Cold Springs Cow Camp, 6,700', 7/1/83; Plot 7028, north of trail 110 ca. ¼ mi west of McGaffee Cow Camp, 5,900', 8/13/83; Plot 7034, just west of trail 110 at the Old Timer Mine and Spring, 6,470', 8/13/83; and Plot 7035, ca. ¼ mi west of the Old Timer Mine and cabin, 6,550', 8/14/83.

Navarretia intertexta (Benth.) Hook. var. *propinqua* (Suksd.) Brand, the short-corolla variety of the Needle-leaf Navarretia.

Scarce, northern Seven Devils, 5,200' ±.

Bingham 539, ID, open, rocky gently west-sloping hillside near ridgetop with shallow, vernally wet soil over basalt, ca. 0.3 mi south from Cow Cr. Saddle along rd. 420, 5,240', 7/21/82.

Phlox austromontana Coville, Desert Phlox.

Frequent, central and southern Seven Devils, 7,000-8,400'.

Bingham and Miller 15, and Bingham 349, ID, bedrock crevices in open ridgetop, ca. 0.2 mi southwest of Heavens Gate Lookout, 8,350', 7/21/79; and south-facing mostly open, moderately dry, rocky hillside in an open *Abies lasiocarpa, Pinus albicaulis* forest bordering a large boulder talus ca. 0.2 mi southwest of the largest and northeasternmost of the lakes in Six Lake Basin, 7,540', 7/18/81; respectively.

Christ 12549, ID, and 12559, ID and WS, on rocky shingle of ridge, Heavens Gate Ridge, 7/12/41; and grassy, semiopen slopes, Heavens Gate Ridge, 7/12/41; respectively.

Ownbey and Meyer 2097, WS, vicinity of Heavens Gate, 6/27/40.

*Packard 333, ?WS, open flat in Dry Diggins area, 7,000', 6/29/37.

St. John and Mullen 8466, WS, Dry Diggins area, 7,000', 7/20/27.

Tisdale 7/17/79, IDF 81079, vicinity of Seven Devils Guard Station, 7,500', 7/17/79.

Wellner 1683, ID, north of the Lookout on Pollock Mt., 8,050', 8/6/78.

Wherry 2541, WS, Black Lake, 7/3/40.

Plus 3 Sight Records by Bingham and Miller.

Phlox colubrina Wherry and Const., Snake River Phlox.

Scarce (mostly at lower elevs.) northern Seven Devils and Rapid River, 5,000-5,600'.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 on a small, grassy-weedy bench ca. 0.1 mi above the Circle C State Fish Hatchery trailhead gate, 2,250', 6/8/82.

C. Johnson Sight Record, Plot 793, ca. 200' southwest of the Grave Point Lookout tower below the rd., 5,550', 6/29/82.

Phlox diffusa Benth. var. *longistylis* (Wherry) Beck., the long-styled variety of Spreading Phlox.

Scarce, central Seven Devils, 7,900-8,400'.

Q. Jones 194, ID and WS, grassy meadow, Heavens Gate Ridge, 7/11/50 (but found to be intermediate with *P. austromontana* Cov., teste Henderson and Bingham).

C. Johnson Sight Record, Plot 7076, east of the Heavens Gate rd. and ca. 1/3 mi south of the lookout parking area, 7,930', 9/2/83 (relation to *P. austromontana* not stated).

Phlox viscida E. Nels., Sticky Phlox.

Uncommon, northern Seven Devils, 5,000-5,600'.

Bingham 455, ID and WS, open basalt-rock slope near ridgetop with a sparse grass-forb-rigid sage stand, immediately north of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.

C. Johnson Sight Records, Plot 781, on the table lands ca. ¼ mi south-southeast of Dixon Corrals, 5,150', 6/25/82; and Plot 793, just southwest of the Grave Point Lookout tower, below the rd., 5,550', 6/29/82.

Meyer 1610, WS, steep open grassy slope above the east side of Sheep Cr., ? elev., 5/12/39.

Packard 80, WS, 4 mi above the mouth of Sheep Cr., 4,000-5,000', 5/16/36.

Polemonium pulcherrimum Hook. (vars. considered weak, not used), Skunk-leaved Jacob's Ladder.

Abundant, entire Seven Devils, 5,700-8,500'.

Baker 12023, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 28 & 89, ID, openings in west-facing rock-boulder slope at the edge of a moderately open *Abies lasiocarpa, Pinus albicaulis* forest, just west of the main Snake-Salmon Rivers divide ca. 0.2 mi southwest of Heavens Gate Lookout, 8,300', 7/21/79; and in the open on a steep, gravelly, northeast-facing slope at the foot of the northwest ridge off He Devil Mt., 8,450', 7/26/79; respectively.

Brewer 107, IDF, at Rock Cr. along the Black Lake rd. 112, 6,500', 7/25/30.

*Christ 8663, 12497, & 12538, ?NY, in meadow in cirque, Pyramid Peak, 8/8/37; in crevices in conifer grove, Seven Devils Camp, 7/12/41; and in tundra on peaks, Heavens Gate, 8,500'. (not over 8,430'), 7/12/41; respectively.

Christ 12482, ID and WS, and 12497, ID, north side of trees, Seven Devils Ridge, 7/11/41; and under conifers, Seven Devils Camp, 7/12/41; respectively.

*Hermann 12048, ?NA, vicinity of Heavens Gate Lookout, 8,400', 8/6/55.

C. Johnson 8/19/83, BKR 2472, Plot 7041, east of trail 214 ca. ¼ mi north of Purgatory Saddle, *Abies lasiocarpa/Luzula hitchcockii* community, 7,510', 8/19/83.

Q. Jones 195, ID and WS, under *Pinus albicaulis*, Heavens Gate, 7/12/50.

Nelson and Nelson 2995, RM, Dry Diggins Lookout, 8/10-15/38.

Packard 298, WS, moist thicket below Hibbs Cow Camp, 7,600', 6/26/37.

*Pennell 20809 & 20812, ?PH, clefts of ryolitic rock, Smith Mt., 7,500-7,700', 7/9/37; and moist slopes, Black Lake, 7,200-7,700', 7/9/37; respectively.

St. John and Mullen 8477, WS, woods, Dry Diggins, 6,500', 7/20/27.

Plus 50 Sight Records by Bingham and Miller and C. Johnson, including vicinities of Cold Springs Lookout site and Myers Cr.

Polemonium viscosum Nutt., Sticky Jacob's Ladder.

Uncommon, high central Seven Devils, 8,700-9,300'.

Bingham and Miller 40, 85, & 97, ID, exposed bedrock crevices on the summit of She Devil Mt., 9,300', 7/23/79; soil pockets atop large boulders in the mammoth boulder field immediately north of the summit of He Devil Mt., 8,700', 7/26/79; and on the small, bedrock bench ca. 50' south and 25' below the summit of He Devil Mt., 9,370', 7/26/79; respectively.

Christ 12460, ID, between rock walls on talus, Seven Devils Ridge, 7/11/41.

*Nelson and Nelson 2962, ?RM, summit of He Devil, 8/10-15/38.

St. John and Mullen 8571, WS, rock crevice on He Devil Mt., 9,100', 7/24/27.

Plygonaceae

Eriogonum compositum Dougl. var. undet., Northern Buckwheat.

Scarce, southern Seven Devils, 5,000' ±.

*Christ 11066, ?NY, on mountainside in Snake River Gorge west of Cuprum, ? elev., 5/30/40.

Eriogonum flavum Nutt. var. *piperi* (Greene) Jones, Piper's Yellow Buckwheat.

Abundant, entire Seven Devils, 6,700-8,400'.

Baker 11297, 11312, & 12004, ID, grassy north slope, Kinney Point, 9/3/53; moist, open grassy slope, Sheep Rock, 9/3/53; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 69 & 83, ID, on an open, bedrock outcrop immediately behind Seven Devils Guard Station, 7,200', 7/24/79; and on the south-facing, rocky slope along trail 123 ca. 1/8 mi west of the south end of Sheep Lake, 8,000', 7/25/79; respectively.

Christ 8707 & 12500, ID, raw, gravelly slopes of high ridges near Black Lake, 8/8/37; and grassy slopes, Seven Devils Camp, 7/12/41.

*Christ 12600, ?NY, crest of ridge, Heavens Gate, 7/13/41.

*Hermann 12040, ?US, summit of ridge at Cold Springs Lookout, 7/6/55.

Q. Jones 216, WS, vicinity of Heavens Gate Lookout, 7/13/50.

Kruckeberg 3190, WS, WTU, open meadowy hillside above Seven Devils Forest (Guard) Station, 2 mi below Saddle (prob. Windy Saddle), 7,000', 7/30/52.

LaZelle 22, ID, open, gravelly, south-facing slope ¼ mi north of Seven Devils Administrative Site (Guard Station), 7,400', 7/29/63.

*Nelson and Nelson 2987, ?RM, Horse Heaven, 8/10-15/38.

Packard 337, WS, vicinity of Hibbs Cow Camp, 7,800', 6/29/37.

St. John and Mullen 8499 & 8609, WS, rocky crest, Dry Diggins, 7,300', 7/20/27; and Sheep Cr. Narrows, 6,800' (prob. The Narrows along the Old Boise Trail ca. 1 mi north of Bald Mt.), 7/26/27; respectively.

Wellner 1682 & 1693, ID, peak at the north end of Pollock Mt., 8,050', 8/6/78; and ca. 1/8 mi west of the south end of Sheep Lake along trail 123, 8,000', 8/21/78; respectively.

Plus 38 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Eriogonum heracleoides Nutt. var. *angustifolium* (Nutt.) Torr. and Gray, the narrow-leaved variety of the Parsley-leaved Buckwheat.

Uncommon, entire Seven Devils, 6,600-8,000'.

Bingham and Miller 149 & 216, ID and WS, in the small meadow ca. 0.1 mi northeast of Hanson Cr. along the Old Boise Trail 101, 6,800', 7/17/80; and in the open rimrock at the east edge of the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. Line, 7,850', 8/25/80; respectively.

Kruckeberg 3204, WS, WTU, on rocky slope and in crevices just below Dry Diggins Lookout, 8/1/52.

Packard 432, WS, dry, open flat, vicinity of Hibbs Cow Camp, 8,000', 7/26/38.

Plus 4 Sight Records by Bingham and Miller, Sawpit Saddle to Purgatory Saddle, 5,000-7,900'.

Eriogonum heracleoides Nutt. var. *heracleoides*, the wide-leaved variety of Parsley-leaved Buckwheat.

Abundant, entire Seven Devils and west fork Rapid River, 5,000-8,000'.

Baker 12050, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 393, ID and WS, open *Pseudotsuga menziesii* forest on rocky, southeast-facing slope along the Old Boise Trail ca. 0.1 mi north of the Cannon Lake trail, 6,500', 7/27/81.

Christ 8598, ID, Smith Mt., 8/8/37.

Lewis 2208 (?2280a), BOIS, OGDF, Steele Stand 72-Pa-25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,130', 6/12/72.

*Nelson and Nelson 2966, RM, Dry Diggins Ranger Station, 8/10-15/38.

Plus more than 48 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Big Canyon Saddle to Lockwood Saddle, 5,000-7,800'.

Eriogonum heracleoides Nutt. var. undet., Parsley-flowered Buckwheat.

*Christ 12692, ?NY, sliderock on west slopes along Sheep Cr. trail (prob. trail 112), 7/17/41.

Plus 1 Sight Record by Steele.

Eriogonum niveum Dougl., Snow Buckwheat.

Scarce (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000' ±.

Bingham and Miller Sight Records: on rocky ridge at Sawpit Saddle, 5,050', 7/8/81; and along the west fork of the Rapid River trail 113, ca. 0.1 mi west of the main forks in sec. 26, 2,800', 6/9/82.

Eriogonum ovalifolium Nutt. var. *depressum* Blank., the greenish-leaved variety of Cushion Buckwheat.

Occasional, central Seven Devils, 8,000-9,400'.

Baker 12005, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Q. Jones 209, ID, rocky soil on exposed ridges, Heavens Gate, 7/12/50.

*Nelson and Nelson 3015, RM, top of He Devil, 8/10-15/38 (prob. the same plant as immediately below).

Eriogonum ovalifolium Nutt. var. *nivale* (Canby) Jones, the white-leaved variety of Cushion Buckwheat (prob. the same plant as Nelson and Nelson 3015, above).

Scarce, high central Seven Devils, 9,200-9,400'.

Bingham and Miller 46 & 95, ID, bedrock crevices ca. 150' north of the summit of She Devil Mt., 9,275', 7/23/79; and bedrock bench ca. 50' south and 25' below the summit of He Devil Mt., 9,370', 7/26/79; respectively.

St. John and Mullen 8542, WS, summit of He Devil, 9,200', 7/24/27.

?*Eriogonum ovalifolium* Nutt. var. *ovalifolium*, Cushion Buckwheat.

Christ 12483, ID and WS, crags and slopes, Seven Devils Ridge, 7/11/41 (but the typical variety is supposed to be a plains and sagebrush desert plant; prob. one of the varieties above).

Eriogonum ovalifolium Nutt. var. undet., Cushion Buckwheat.

Christ 8417, ID, high, rocky ridge near Black Lake, 8/8/37.

Eriogonum sphaerocephalum Dougl. var. *halimioides* (Gangd.) Stokes, the whitish-perianthed variety of Rock Buckwheat.

Scarce, southern Seven Devils, 5,000' ±.

Christ 8589, ID, on basalt scabland 6 mi north of Bear (prob. along rd. 105 south of the Black Lake rd. 112), 8/8/37.

E. Johnson 7/20/31, Herb. unknown, Black Lake to Bear P.O., Seven Devils Mt., 7/20/31 (from Hitchcock and others, Pt 2, p. 131, 1964).

Eriogonum umbellatum Torr. var. *stellatum* (Benth.) Jones, the variety of Sulphur Buckwheat having branched umbel rays and tomentose leaves.

Scarce, southern Seven Devils, 6,000-8,000'.

*Christ 8615, ?NY, gravel slide, Smith Mt. rd., 8/8/37.

Eriogonum umbellatum Torr. var. *umbellatum*, Sulphur Buckwheat.

Scarce, central Seven Devils, 7,200' +.

Baker 12082, ID, dry, gravelly soil on a point above Seven Devils Guard Station, 7/21/54.

Eriogonum umbellatum Torr. var. undet., Sulphur Buckwheat.

*Christ 12622, ?NY, on andesite knolls of dissected plateau, Hibbs Cow Camp, 7/15/41.

Oxyria digyna (L.) Hill, Mountain Sorrel.

Frequent, central and southern Seven Devils, 7,600-9,300'.

Baker 12264, ID, dry, gravelly hillside on the west slope of Heavens Gate, 7/31/54.

Bingham and Miller 14 & 45, ID, and 224, ID and WS, protected west-facing slope in the lee of boulders on the main Snake-Salmon Rivers divide, with sparse but lush, low, subalpine forb vegetation, 0.2 mi south-southwest of Heavens Gate Lookout, 8,350', 7/21/79; crevices in open, bedrock ridgetop, summit of She Devil Mt., 9,300', 7/23/79; and 3/4-open, west-facing talus slope with luxuriant forb stand recently under snowbank, under the rimrock along the northwest edge of the Horse Heaven Lookout pasture ca. ¼ mi southwest of the Lookout cabin, 8,000', 8/25/80; respectively.

*Christ 8678, 12447, & 12544, ?NY, among rocks on talus slope on Pyramid Peak, 8/8/37; on cliffs above Seven Devils Lake, 7/11/41; and in lee of cliffs on peak, Heavens Gate, 7/12/41; respectively.

St. John and Mullen 8575, WS, He Devil Mt., 9,000', 7/24/27.

Plus 12 Sight Records by Bingham and Miller.

Polygonum aviculare L., Doorweed.

Scarce (mostly at lower elevs.), central Seven Devils, 5,000' ±.

Bingham and Miller 578, ID and WS, open gravelly roadbed of rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Polygonum bistortoides Pursh, Bistort.

Frequent, central and southern Seven Devils, 7,000-7,800'.

Bingham and Miller 421, ID, 2/3 open, deep silty loam, moderately moist flat in an open *Abies lasiocarpa, Picea engelmannii, Pinus contorta* forest, along trail 112 on the low ridge at the very head of Bernard Cr., ca. ½ mi southwest of the jct. of trails 112, 57, and 140 at the Iron Phone, 7,400', 8/10/81.

*Christ 12642 & 12715, ?NY, small meadow in talus, Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41; and in marsh at Lily Pad Lake, 7/17/41; respectively.

Packard 307, WS, rocky, springy hillside near 2d Sheep Cr. Lake (Shelf Lake), 8,300', (lake lies at 7,350'), 6/27/37.

St. John and Mullen 8481, WS, Dry Diggins, 7/20/27.

Plus 5 Sight Records by Bingham and Miller, Dry Diggins Ridge to south of Joes Gap, 7,000-7,800'.

Polygonum douglasii Greene var. *douglasii*, Douglas Knotweed.

Scarce, central Seven Devils, 6,900' ±.

C. Johnson Sight Record, Plot 7045, east of trail 214 ca. ½ mi south of Stevens Saddle, 6,900', 8/19/83.

Polygonum douglasii Greene var. *latifolium* (Engelm.) Greene, the montane variety of Douglas Knotweed, or Mountain Knotweed.

Common, entire Seven Devils, 5,200-8,100'.

Baker 11325 & 12048, ID, dry hillside 6 mi north of Cuprum (prob. along rd. 106), 9/3/53; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 218A, ID and WS, gently south-sloping, open sedge-forb meadow at the east edge of the Horse Heaven Lookout pasture just north of the Idaho-Adams Co. line, 7,850', 8/25/80.

Plus 19 Sight Records by Bingham and Miller, Grave Point Lookout to Kinney Point, 5,200-8,100'.

Polygonum douglasii Greene var. undet., Douglas or Mountain Knotweed.

*Christ 11075 & 12722, ?NY, mountainside in Snake River Gorge west of Cuprum, 5/30/40; and basaltic knoll near Sheep Cr. Swamp, 7/17/41; respectively.

Plus Steele Sight Records: along the Bear-Indian Crs. divide off rd. 002, 5,100-5,130', 6/12/72; and Tisdale Sight

Records, vicinities of Cold Springs Cow Camp and Cold Springs Lookout, 6,600-6,700', 7/11-13/79.

Polygonum majus (Meisn.) Piper, Palouse Knotweed.

Uncommon, entire Seven Devils, 5,100-7,500'.

C. Johnson Sight Records: Plot 7009, above the Old Boise Trail 101 ca. ¼ mi southeast of Haas Lake, 7,350', 8/9/83; Plot 7065, at the end of the 1st long switchback ascending trail 214 southwest from Black Lake, 7,460', 8/30/83; Plot 7067, below trail 217 in the head of Deep Cr. ca. 0.1 mi northwest of the Black Lake rd. 112, 7,150', 8/31/83; Plot 7068, below trail 217 in the head of Deep Cr. ca. ¼ mi northwest of the Black Lake rd. 112, 6,960', 8/31/83; and Plot 7071, east of the Old Boise Trail 101 in the head of Kessler Cr., 6,780', 9/1/83.

Tisdale 7/13/78, IDF 78360, vicinity of Low Saddle, 5,150', 7/13/78.

Polygonum minimum Wats., Leafy Dwarf Knotweed.

Uncommon, central Seven Devils, 6,600-8,000'.

Bingham and Miller 363, ID, half-shaded, east-facing, gently sloping streambottom trail tread under an open *Abies lasiocarpa-Pinus albicaulis* forest, ca. 25' down Bridge Cr. from the outlet of Mirror Lake, 8,000', 7/26/81.

Christ 12606, ID, dry cliffs in cirque below Seven Devils Lake, 7/13/41.

Plus 4 Sight Records by Bingham and Miller, Cannon Lake trail, Triangle Lake trail, Hanson Lakes manway, and Horse Heaven Lake, 6,600-7,600'.

Polygonum phytolaccaefolium Meisn., Alpine Knotweed.

Abundant, central and southern Seven Devils, 6,400-8,100'.

Baird 7/29/71, Council R.D., open hillside below Smith Mt. Lookout, 7,000', 7/29/71.

Baker 12015, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 66, ID, east-facing, moderately dry, open, rocky hillside immediately east of Seven Devils Guard Station, 7,200', 7/24/79.

*Christ 8703, ?NY, pure, heavy stand on the rawer coarse talus slopes near Black Lake, 8/8/37.

Christ 12505, WS, rocky outcrops and shallow soils, Seven Devils Camp, 7/12/41.

Q. Jones 207, WS, vicinity Heavens Gate Lookout, 7/12/50.

Kruckeberg 3189, ID, WS, WTU, meadowy hillsides above Seven Devils Guard Station 2 mi below Windy Saddle, 7,000' (must be at least 7,200' if above Station), 7/30/52.

St. John and Mullen 8506, WS, gravel flat on Dry Diggins, 7/21/27.

Plus 38 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, including vicinity of Cold Springs Lookout site.

?*Polygonum watsonii* Small, Water Knotweed.

*Christ 8658, ?NY, meadow in cirque, Pyramid Peak, 8/8/37 (but mostly of the lowlands and not known for Idaho).

Rumex acetosella L., Sheep or Horse Sorrel (European weed).

Common, entire Seven Devils and Rapid River, 5,000-8,000'.

Bingham and Miller 183, ID and WS, east-facing opening in a *Pseudotsuga menziesii* stand along the Old Boise Trail ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 8/18/80.

Brewer 53, Council R.D., ¼ mi east of Krammer, sec. 6, T. 20 N., R. 2 W. (prob. along either rd. 105 or 112), 5,000', 6/21/29.

*Christ 8623, ?NY, roadside, Black Lake, 8/8/37.

Davis 2233, WS, moist hillside, Grave Point Lookout, 6/24/40.

Plus 21 Sight Records by Bingham and Miller, Big Canyon Saddle south to Black Lake, 5,000-8,000'.

Rumex crispus L., Curly Dock (European weed).

Scarce (mostly at lower elevs.), northern Seven Devils, 5,200' ±.

Bingham 544, ID, open, southwest-facing, basalt-rock roadside at the edge of a grass-forb-rigid sage stand along rd. 420 ca. 0.1 mi south of Cow Cr. Saddle, 5,240', 7/21/82.

Rumex salicifolius Weinm. ssp. *triangulivalvis* Danser var. *montigenitus* Jeps., the northern Rocky Mountain variety of the triangular-valved subspecies of Western Dock.
Scarce, central Seven Devils, 7,200' ±.
Bingham and Miller 443, ID, drawn-down southeast shoreline of Ruth Lake, 7,200', 8/17/81.

olypodiaceae

***Adiantum pedatum* L., prob. a new, high-elevation taxon of the Maidenhair Fern.
Rare, 7,700-8,000' +, known only from 3-4 localities in the high, central Seven Devils, all within 1½ mi of each other. This probable new taxon occurs 3,500' above the usual distribution of Idaho *A. pedatum*, and has erect (instead of horizontal) pinnae that impart a storied appearance (may disappear in pressing). Recommended for a "Federal Watch List" of plants rare in the U.S. but not currently threatened without major changes in local land use (cf. Steele and others, 1981).
Bingham and Miller 34 & 70, ID, & 118, ID and WS, under the overhang of a low cliff just west of the Goat Pass manway where leaving the northeast end of the small, unnamed pond at the east side of Sheep Lake, 7,880', 7/22/79; in the field of medium-sized boulders along trail 123 between the 4th and 6th switchbacks ca. 1/8 mi west of the south end of Sheep Lake, 8,000', 7/25/79; and at the toe of the large-rock talus slope along the north side of Hanson Cr. just above the cirque dropoff ca. ¼ mi below Lower Hanson Lake, 7,700', 7/15/80; respectively. The locality of collection 70 is identical with that of Wellner 1691, below, and may be identical with Packard 309 and St. John and Mullen 8563, below.
Packard 309, WS, foot of He Devil Mt. at the 4th Sheep Cr. Lake (Sheep Lake), 9,000' (prob. after St. John's elev., below; cannot be over 8,400' according to Packard's route near present trail 123), 6/27/37. Possibly the identical locality as Bingham and Miller 70, and Wellner 1691.
St. John and Mullen 8563, WS, "Pinnae erect", under large boulders on He Devil Mt., 9,000', 7/24/27. The original collection of this probably new taxon; possibly from the same locality as Bingham and Miller 70, Packard 309, and Wellner 1691. The author and C. J. Miller found no *A. pedatum* on He Devil Mt. at 9,000'.
Wellner 1691, ID, same locality and population as Bingham and Miller 70, above, 8,000', 8/21/78.

Aspidotis densa (Brackenr.) Lellinger, Podfern.
Occasional, central Seven Devils, 7,600' ±.
*Christ 12593 & 12700, ?NY, on cliffs in cirque below Seven Devils Lake, 7/13/41; and fissures in cliff ledges along the Sheep Cr. trail, 7/17/41; respectively.
Ownbey and Meyer 2079, WS, rock crevices, east slope, headwaters of Sheep Cr., 6/26/40.

Athyrium distentifolium Tausch var. *americana* (Butters) Cronq., Alpine Lady-fern.
Frequent, central and southern Seven Devils, 7,200-9,000'.
Christ 8688, WS, on high talus slopes, Black Lake, 8/8/37.
*Christ 12551, ?NY, cliffs on ridge, Heavens Gate, 7/12/41.
St. John and Mullen 8548, WS, in crevices in moist rock slide, He Devil Mt., 9,000', 7/24/27.
Steele 936, BOIS and IDF, growing in rocks at Heavens Gate, 8,400', 9/8/74.
Wellner 1690 & 1695, ID, east side of the summit of Pollock Mt., 8,040', 8/6/78; and bottom of the west fork of the west fork of Sheep Cr., along trail 123 just below Gem Lake, 7,750', 8/21/78; respectively.

Athyrium filix-femina (L.) Roth, Lady-fern.
Uncommon, fairly low elevs. in the northern and central Seven Devils, 5,900-7,700'.

Baird 8/18/71, Council R.D., on small seep 1 mi above Bear Guard Station, 5,200', 8/18/71.

Baker 12258, ID, moist woods along Shingle Cr. (prob. the north fork along rd. 517), 7/31/54.

Bingham and Miller 394, bottom of Bridge Cr. ca. ¼ mi below Mirror Lake, 7,700', 7/26/81.

Plus 5 Sight Records by Bingham and Miller, Caribou Cr. to trail 124 just north of the south fork of Little Granite Cr., 5,900-6,900'.

Cheilanthes feei Moore, Fee's Lip-fern.

Scarce, central and southern Seven Devils, 7,200-7,800'.

Bingham 324, ID, in rock crevices of outcrop in opening in *Abies lasiocarpa* stand just northwest of Black Lake, 7,200', 7/17/81 (intermediate with *C. gracillima* Eat. having both a scaly rachis, and pinnules exceeding 1½ cm long).

*Christ 12461, ?NY, cliff crevices, Seven Devils Ridge, 7/11/41.

Plus 1 Sight Record by Bingham, ½ mi north of the summit of trail 218 between Black Lake and Joes Gap, 7,800', 7/18/81.

Cheilanthes gracillima D.C. Eaton, Lace Lip-fern.

Common, central and southern Seven Devils, 6,400-8,400'.

Bingham and Miller 58 & 399, ID, east-facing bedrock crevices at Goat Pass (ca. ¼ mi west and above Mirror Lake on the Bridge-Sheep Crs. divide), 8,400', 7/24/79; and ca. ¼ mi south-southwest of the Seven Devils Guard Station in the bottom of the dry fork or Bridge Cr. below Seven Devils Lake, on cliff crevices in open forest, 7,300', 7/26/81; respectively.

*Christ 8693, ?NY, rock spurs, Pyramid Peak (south-southwest of Black Lake), 8/8/37.

Christ 12595, WS, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Munro 75, WS, rock crevices in saddle of Seven Devils Mts., 5/14/37.

St. John and Mullen 8462, WS, rocky crevices, Dry Diggins Area, 7,000', 7/20/27.

Wellner 1689 & 1698, ID, north of the Lookout on Pollock Mt., 8,050', 8/6/78; and north of the Echo Lake trail 129 northwest of Echo Lake, 7,100', 8/22/78; respectively.

Plus 13 Sight Records by Bingham and Miller and C. Johnson.

Cryptogramma crispa (L.) R. Br. var. *acrostichoides* (R. Br.) B. Clarke, the North American and East Asian variety of Rock Brake.

Common, central and southern Seven Devils, 5,300-8,400'.

Baker 12285, ID, rock crevices west of Seven Devils Camp, 7/31/54.

Bingham and Miller 61, ID, on an east-facing cliff immediately south of Goat Pass, on the Bridge-Sheep Crs. divide ca. ¼ mi west of Mirror Lake, 8,400', 7/24/79.

*Christ 8709 & 12597, ?NY, in crevices on cliffs, Pyramid Peak, 8/8/37; and on cliffs in cirque below Seven Devils Lake, 7/13/41; respectively.

C. Johnson 8/9/83, BKR 2443, Plot 7007, east-facing moraine at northeast end of Haas Lake, *Carex hoodii-Potentilla glandulosa* moraine community, 7,240', 8/9/83.

Packard 458, WS, west slope along the Brundage trail between the forks of Sheep Cr., 7,500', 7/28/38.

Pennell 20815, PH, crevices of rhyolite, Black Lake, 7,200-7,700', 7/9/37.

St. John and Mullen 8387, WS, McGaffee Cow Camp, 5,400', 7/17/27.

Plus 15 Sight Records by Bingham and Miller.

Cystopteris fragilis (L.) Bernh., Brittle Bladder-fern.

Uncommon, northern and central Seven Devils and Rapid River, 5,000-8,300'.

Bingham and Miller 72, ID, & 187 & 476, ID and WS, in crevices of large, broken boulders at edge of subalpine forest, in the valley ca. 3/5 mi directly north of the summit of He Devil Mt., 8,250', 7/25/79; moderately open Douglas-fir forest on an east-facing slope ca. 1/2-3/4 mi north of

Hanson Cr. along the Old Boise Trail 101, 6,800', 7/18/80; and shady river bottom with an *Abies grandis, Pseudotsuga menziesii, Taxus brevifolia* stand along the lower Rapid River trail 113 near the mouth of Blue Gulch, 2,400', 6/8/82; respectively.

*Christ 12594, ?NY, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Q. Jones 218, ID and WS, cracks in rocks near snowline, Heavens Gate, 7/13/50.

Plus 3 Sight Records by Bingham and Miller, and C. Johnson, near jct. trails 112, 140, & 57, along trail 112 ca. 1/3 mi west of the Windy Saddle trailhead, in the head of the east fork of Sheep Cr., and along rd. 2060 near Lost Valley Cr., 5,100-7,100'.

Pellaea breweri D. C. Eat., Brewer's Cliff-brake.

Scarce, southern Seven Devils, 8,100' ±.

Bingham 341, ID, on rock outcrops on an open, east-facing slope with sedge-grass-forb stand, ca. ½ mi west of Black Lake along the Six Lake Basin trail 218 just east of the trail's summit between Black Lake and Joes Gap, 8,100', 7/18/81.

***Polystichum kruckebergii* Wagner, Kruckeberg's Sword-fern.

Rare, central Seven Devils, 7,500' ± (recommended for a "Federal Watch List" of rare U.S. plants not currently threatened unless major changes in land use occur, cf. Steele and others, 1981).

Kruckeberg 3192, ID, NY, OSC, WS, WTU, on talus and in crevices above Sheep Cr. Lake No. 2 (Shelf Lake), 7,500', 7/31/52.

Polystichum lonchites (L.) Roth, Mountain Holly-fern.

Uncommon, central Seven Devils, 5,700-9,000'.

Bingham and Miller 195 & 364, ID, northeast-facing, 1/3-shaded, stable, moist, large-rock talus along the Old Boise Trail 101 just south of the rockslides ca. 0.2 mi south of Cannon Cr., 6,800', 7/18/80; and east-facing, open, steep, rocky streambed ca. ¼ mi down Bridge Cr. from the outlet of Mirror Lake, 7,700', 7/26/81; respectively.

Christ 12459, ID, crevices in cliffs above Seven Devils Lake, 7/11/41.

St. John and Mullen 8541, WS, rock chimney on He Devil Mt., 9,100', 7/24/27 ("rare").

Plus 2 Sight Records by Bingham and Miller, east fork Sheep Cr., 5,750' and 7,100'.

Polystichum scopulinum (D. C. Eat.) Maxon, Rock Sword-fern.

Frequent, central Seven Devils and west fork Rapid River, 7,000-9,000'.

Bingham and Miller 65, 384, & 450, ID, & 258, ID and WS, outcrop crevices of the east-facing (Mirror Lake side) of the Bridge-Sheep Crs. divide at Goat Pass, ca. 200' down the long talus slope descending to the Lake, 8,200', 7/24/79; south-facing, 1/3-open, cliff base in a moderately dry, open *Pseudotsuga menziesii-Abies lasiocarpa* forest ca. 3/4 mi up the Hanson Lakes manway from the Old Boise Trail 101, 7,700', 7/29/81; southeast-facing, consolidated, moderately dry, and open boulderfield on the northwest bank of Horse Heaven Lake, 7,600', 8/18/81; and in the open, north-facing boulderfield along the west side of the trail immediately north of Dry Diggins Lookout, 7,800', 8/28/80; respectively.

Christ 12470 & 12535, ID, in crevices on rocky shelf, Seven Devils Ridge, 7/11/41; and ledges near peak, Heavens Gate, 7/12/41; respectively.

Packard 428, WS, cool crevices in cliffs and shaded talus slopes on summits near Hibbs Cow Camp, 8,500', 7/23/38.

*Nelson and Nelson 2965, ?RM, summit of He Devil, 8/10-15/38.

Plus 4 Sight Records by Bingham and Miller and Kruckeberg (with his 3192, above), including along the west fork of the Rapid River between Hanson Cr. and trail 62.

Pteridium aquilinum (L.) Kuhn var. *pubescens* Underw., Bracken Fern.

Uncommon, central and southern Seven Devils, 5,800-7,300'.

Baird 8/18/71, Council R.D., on small seep 1 mi above Bear Guard Station, 5,000', 8/18/71.

Bingham and Miller 230, ID and WS, east-facing, open, rocky slope in a moderately dry open forest of *Abies lasiocarpa* and *Pinus albicaulis*, slopes below Horse Heaven Lake, 7,500', 8/26/80.

Brewer 76, Council R.D., Krammer Cabins, sec. 1, T. 20 N., R. 3 W. (prob. along rd. 105), 5,000', 8/9/29.

Plus 5 Sight Records by Bingham and Miller, Bernard Lakes to the Old Boise Trail between Hanson and Dog Crs., 6,800-7,400'.

Woodsia oregana D. C. Eaton, Oregon Woodsia.

Common, entire Seven Devils and Rapid River, 5,300-8,000'.

*Christ 12693, ?NY, ledges in cliffs along the Sheep Cr. trail (112), 7/17/41.

19 Bingham and Miller Sight Records: Big Canyon Saddle south to Joes Gap, and west fork Rapid River, 5,000-8,000'.

Tisdale Sight Record, vicinity of Low Saddle, 5,200', 7/13/78.

Polytrichaceae

Polytrichum ? juniperinum Hedw., True Moss.

Abundant, entire Seven Devils, 5,700-8,000'.

Bingham and Miller 427, ID and WS, half-shaded flat off the west end of the Bernard Lakes at edge of an open *Pinus contorta-Abies lasiocarpa-Picea engelmannii* forest, just west of the westernmost of the Lakes, 7,200', 8/11/81.

Plus many Sight Records by Bingham and Miller, Big Canyon Saddle to Horse Mt., 5,000-8,000'.

Portulacaceae

Calyptridium umbellatum (Torr.) Greene var. *caudiciferum* (Gray) Jeps., the short-leaved, perennial variety of Pussypaws.

Occasional, central Seven Devils, 7,500-8,300'.

Henderson 3850, ID, near the jct. of trails 112 & 56 ca. ¼ mi north-northeast of Hibbs Cow Camp, 7/7/77.

Q. Jones 229, WS, on gravel-size rock near ridgetop ca. ¼ mi south of Heavens Gate Lookout, 7/13/50.

Ownbey and Meyer 2080, WS, gravelly, exposed ridges near Hibbs Cow Camp, 6/26/40.

Packard 471, WS, dry soil on open ridge near Hibbs Cow Camp, Dry Diggins, 8,000', 7/28/38.

Calyptridium umbellatum (Torr.) Greene var. *umbellatum*, the long-leaved, annual variety of Pussypaws.

Frequent, central and high eastern and southern Seven Devils, 7,600-8,400'.

Bingham and Miller 112 & 213, ID and WS, on the open, gravelly surface of weathered ?basalt immediately northeast of Windy Saddle, 7,600', 7/14/80; and on open, gravelly soil ca. 250' north-northeast of the Horse Heaven Lookout cabin, 8/25/80; respectively.

*Christ 8713 & 12555, ?NY, raw, granitic gravels on high slopes and ridges near Black Lake, 8/8/37; and rocky shingle of ridge, Heavens Gate, 7/12/41; respectively.

Henderson 3848A, ID, near the jct. of trails 56 and 112 ca. ¼ mi north-northeast of Hibbs Cow Camp, 7/7/77.

St. John and Mullen 8535, WS, alpine gravels, Dry Diggins, 8,000', 7/22/27.

Wellner 1687, ID, summit of Pollock Mt. north of the Lookout, 8,050', 8/6/78.

Plus 4 Sight Records by Bingham and Miller.

Calyptridium umbellatum (Torr.) Greene var. undet., Pussypaws.

Baker 12078, ID, dry, gravelly soil on open slope above Seven Devils Guard Station, 7/21/54.

Claytonia lanceolata Pursh. var. *lanceolata*, Lance-leaved Spring Beauty.

Frequent, entire Seven Devils, 5,000-8,200'.

Bingham and Miller 71, ID, in open, sedgy valley bottom ca. ½ mi due north of the summit of He Devil Mt., 8,200', 7/25/79.

*Christ 12650 & 12662, ?NY, soil pockets on ridges between

Sheep Cr. Lakes No. 3 and No. 4 (Gem and Sheep Lakes), 7/16/41; and soil pockets on talus slopes, Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41; respectively.

Moore 89, WS, ¼ mi down the Bernard Cr. trail (110) from McGaffee Cow Camp, 7,500' (prob. closer to 5,400'), 5/16/36.

Munro 77, WS, ridge north of Cow Camp (McGaffee's) at the head of Bernard Cr., 4,500' (camp is at 5,700'), 5/14/37.

Packard 584, WS, north slope near Stormy Point, 5/13/39.

Plus 9 Sight Records by Bingham and Miller and C. Johnson.

Claytonia megarhiza (Gray) Parry var. *bellidifolia* (Rydb.) Hitchc., the variety of Alpine Spring Beauty having single leaf veins.

Occasional, central Seven Devils, 8,400-9,000'.

Christ 12463, ID, rock crevices, Seven Devils Ridge, 7/11/41.

St. John and Mullen 8569, WS, rock chimneys on He Devil Mt., "rare", 9,000', 7/24/27.

Henderson Sight Record, along the west fork Sheep Cr. - Bridge Cr. divide ca. ½ mi west of Seven Devils Lake, 8,600', 7/5/77.

Lewisia columbiana (Howell) Robins. var. *wallowensis* Hitchc., the Wallowa Mountains variety of the Columbia Lewisia.

Common, entire Seven Devils, 5,200-8,400'.

Baker 12277, OSC, open, gravelly slopes west of Seven Devils Camp, 7/31/54.

Bingham and Miller 29, ID, in crevices of glaciated bedrock on the peninsula between Sheep Lake and the pond at its northeast corner, 7,845', 7/22/79.

Christ 12490, IDS, on shallow slopes in crevices and crannies, Seven Devils Ridge, 7/11/41.

Q. Jones 214, ID, Heavens Gate, 7/13/50.

Meyer 1618, WS, ridge above east side of Sheep Cr., ? elev., 5/12/39.

Munro 99, WS, rocky outcrop, foot of Seven Devils Mt., north side, 6,000', 5/14/37.

Ownbey and Meyer 2069, WS, headwaters of Sheep Cr. (along trail 112), 6/26/40.

Packard 303, WS, rock outcroppings near foot of He Devil Mt., 8,800' (prob. 8,400' at max.), 6/27/37.

Sharsmith 4016, WS, rim of Snake River Canyon in Sheep Cr., 5,500', 5/12/39.

St. John and Mullen 8396, WS, McGaffee Cow Camp, 5,400', 7/17/27.

Tisdale 7/13/78, IDF 78353, rocky ridge ¼ mi east of Low Saddle, 5,200', 7/13/78.

Plus 17 Sight Records by Bingham and Miller and C. Johnson.

Lewisia pygmaea (Gray) Robins. var. *nevadensis* (Gray) Fosberg, Nevada Lewisia.

Uncommon, central Seven Devils, 7,000-8,400' minus.

Christ 12665 & 12666, ID, & 12723, WS, soil pockets on talus slope, Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41 (rose-pink flowers); ditto 12665 but with white flowers; and seepy alluvial fill of old lake bed near Sheep Cr. swamp, 7/17/41; respectively.

*Christ 12469 & 12713, ?NY, open slopes on high ridges, Seven Devils Ridge, 7/11/41; and hummocks in marsh about Lily Pad Lake, 7/17/41; respectively.

*Kruckeberg 3198, ?WTU, in moist depressions along flats of Dry Diggins area, 7,000', 8/1/52 (pink flowered).

Lewisia pygmaea (Gray) Robins. var. *pygmaea*, Alpine Lewisia.

Scarce, central Seven Devils, 7,300' ±.

Packard 324, WS, the swamps near Lily Pad Lake, 7,900' (elev. Lily Pad Lake and nearby wet, sedge meadow is 7,300'), 6/28/37.

Lewisia triphylla (Wats.) Robins., Three-leaf Lewisia.

Occasional, central Seven Devils, 7,200-7,600'.

*Christ 12452 & 12725, ?NY, soil pockets in cliffs above Seven Devils Lake, 7/11/41; and on basaltic knolls about Sheep Cr. swamp, 7/17/41; respectively.

St. John and Mullen 8507, WS, gravelly flat, Dry Diggins, 8,000', 7/21/27.

Montia arenicola (Hend.) Howell, Sand Montia.

Scarce, lower Rapid River only, 2,500' ±.

Bingham and Miller 491, ID and WS, northwest-facing, half-open, moss-consolidated talus in *Abies grandis, Pseudotsuga menziesii, Taxus brevifolia, Betula occidentalis, Acer glabrum* riparian forest, ca. 0.6 mi up the lower Rapid River from Blue Gulch along trail 113, 2,480', 6/8/82.

Montia cordifolia (Wats.) Pax and Hoffm., Broadleaved Montia.

Common, entire Seven Devils and west fork Rapid River, 5,800-7,600'.

Baker 12283, ID, stream on west side of Heavens Gate (possibly the old stock watering spring stream), 7/31/54.

Bingham and Miller 124, ID and WS, creek bottom under dense *Picea engelmannii, Abies lasiocarpa, Pseudotsuga menziesii* forest, just above the Old Boise Trail 101 at Hanson Cr., 6,800', 7/16/80.

Christ 12576, ID, banks of creek from Seven Devils Lake, 7/13/41.

Davis 2328 & 2351, WS, shady, wet creek bottom Sheep Cr. (prob. the west fork along trail 112), 6/26/40; and 9 mi southwest of Riggins (prob. along rd. 517 in Shingle or the south fork Papoose Crs.), 6/28/40.

Plus 21 Sight Records by Bingham and Miller (almost always present in creeks above 6,000' in entire Seven Devils and west fork Rapid River).

Montia parvifolia (Moc.) Greene, var. intergradient between vars. *parvifolia* and *flagellaris* (Bong.) Hitchc.; or between the narrow-leaved and broad-leaved varieties of the Little-leaf Montia.

Scarce, central Seven Devils, 5,000' minus.

Bingham and Miller 573, ID and WS, steep, north-facing roadcut along rd. 517 in a *Pseudotsuga menziesii/Physocarpus malvaceus* h.t., ca. ¼ mi above the road's 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Montia perfoliata (Donn) Howell, Miner's Lettuce.

Uncommon (mostly from lower elevs.), entire Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller Sight Records: in the campground area on the northwest shores of Black Lake, 7,200', 7/17/81; along the stock drive portion of trail 104 ca. 1/3 mi east of Big Canyon Saddle, 4,700', 6/11/82; along rd. 1819 ca. ¼ mi southwest of Caribou Cr., 6,100', 7/18/81; along trail 110 ca. 1/8 mi east of McGaffee Cow Camp, 5,800', 8/12/81; along the lower Rapid River Trail 113 ca. 1.0 mi above the Circle C State Fish Hatchery trailhead gate, 2,300', 6/8/82; and along trail 214 ca. ½ mi north of Purgatory Saddle, 7,600', 7/17/81.

Montia sibirica Howell var. *sibirica*, Candy Flower.

Scarce, southern Seven Devils, 7,200' +.

*Christ 8634, ?NY, springy places on mountainside, Black Lake, 8/8/37.

Potomogetaceae

Potomogeton natans L., Floating-leaved Pondweed.

Scarce, central Seven Devils, 7,300' ±.

St. John and Mullen 8589, WS, Lily Pad Lake, Dry Diggins, 8,000' (true lake elevation 7,300'), 7/25/27.

Primulaceae

Dodocatheon conjugens Greene var. *conjugens*, Slimpod Shooting-star.

Occasional, west-central and northern Seven Devils, 5,000-5,700'.

Moore 92, WS, in pine timber at McGaffee Cow Camp, 8,600' (true camp elevation 5,700'), 5/16/36.

Munro 76, WS, Cow Camp at head of Bernard Cr., 4,500' (prob. McGaffee Cow Camp at 5,700'), 5/14/37.

Packard 585, WS, near Stormy Point (southwest of Low Saddle), 5,500', 5/13/39.

Dodocatheon jeffreyi van Houtte, Jeffrey's Shooting-star.

Frequent, central and southern Seven Devils, 7,200-8,000'.

Baird 7/29/71, Council R.D., moist area at base of snowbank ¼ mi north of High Dive, 7,500', 7/29/71.

Bingham 317 & 339B, ID and WS, open, northwest-facing sedge meadow at the foot of a cirque wall, ca. ½ mi northwest of High Dive Point along the Black Lake rd. 112, 7,550', 7/16/81; and north-northwest-facing, half-shaded streambank in an *Abies lasiocarpa/Pinus albicaulis* forest along trail 214 ca. ½ mi north of Purgatory Saddle, 7,620', 7/17/81.

*Christ 8661 & 12652, ?NY, in meadow in cirque, Pyramid Peak (south-southwest of Black Lake), 8/8/37; and marshy bank of Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41; respectively.

Packard 325, WS, in the swamps near Lily Pad Lake, 6/28/37.

St. John and Mullen 8479 & 8512, WS, both streamside near Dry Diggins, 7,200' and 8,000', 7/20 and 12/27, respectively.

Plus 8 Sight Records by Bingham and Henderson and Bingham and Miller.

Dodocatheon pulchellum (Raf.) Merrill var. *monanthum* (Greene) Hitchc., the reddish-purple stamened variety of the Dark-throat Shooting-star.

Scarce, central Seven Devils, 7,800' ±.

Packard 301, WS, moist-wet soils at Sheep Cr. Lake No. 4 (Sheep Lake) at the foot of He Devil Mt., 9,000' (true lake elev. 7,825' elev.), 6/27/37.

Dodocatheon pulchellum (Raf.) Merrill var. *pulchellum*, the yellow-stamened variety of the Dark-throat Shooting-star.

Occasional, northern and central Seven Devils and Rapid River, 5,200-7,600'.

Bingham 466 and Bingham and Miller 496, ID and WS, on a basalt-rock, open ridgetop immediately north of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82; and on a southeast-facing, 3/4-shaded, moderately moist *Pseudotsuga menziesii, Pinus contorta, Abies grandis, Larix occidentalis* forest slope ca. ¼ mi up the west fork Rapid River trail 113 from Deep Cr., 4,300', 6/9/82; respectively.

Christ 12499, ID, rock crevices in wet cliffs above Seven Devils Lake, 7/11/41.

Dodocatheon pulchellum (Raf.) Merrill var. undet.

Baird 5/1/72, Council R.D., moist spring area 1 mi above Bear Post Office, 5,500', 5/1/72.

Primula cusickiana Gray, Cusick's Primrose.

Occasional, central and southern Seven Devils, 5,000-6,000'.

Brewer 7, Council R.D., Sheep Peak (or Mt., not Sheep Rock), sec. 11, T. 18 N., R. 4 W., 5,200', 5/9/28.

Meyer 851, WS, Seven Devils Mts., south slopes, sec. 2, T. 23 N. (?T. 24 N.), R. 2 W. (? along trail 112 or 140), ? elev., 5/13/37.

Munro 70, WS, south exposure at foot of Seven Devils Mts., 6,000', 5/14/37 (possibly the same locality as Meyer 851, above, and the elev. of 6,000' puts it on the north fork Bernard - Sheep Cr. ridge above McGaffee Cow Camp, certainly a far more plausible locality for this plant to be blooming in mid-May than at Meyer's stated locality in sec. 2, ca. 1 mi north of Lily Pad Lake, elev. 7,300' ±).

anunculaceae

Aconitum columbianum Nutt. var. *ochroleucum* A. Nels., the cream-flowered variety of Monkshood.

Common, central Seven Devils, 6,400-7,300'.

Baird 8/5/71, Council R.D., ¼ way through Landore-Cuprum rd. (105), 5,000', 8/5/71.

Bingham and Miller 240, ID and WS, in a small marsh ca. 0.1 mi east of Ruth Lake and just south of the Ruth Lake trail, 7,200', 8/27/80.

*Christ 8621 & 12696, ?NY, springy place on mountainside, Black Lake, 8/8/37; and moist places at Sheep Cr. crossing (prob. along trail 112 at the west fork of Sheep Cr.), 7/14/41; respectively.

Packard 446, WS, moist shaded meadow by small stream, Lily Pad Lake, 7/28/38.

St. John and Mullen 8482, WS, meadow on Dry Diggins, 7/20/27.

Plus 17 Sight Records of Bingham and Miller and C. Johnson.

Actaea rubra (Ait.) Willd., Western Red (or white) Baneberry.

Frequent, entire Seven Devils and Rapid River, 5,000-7,500'.

Bingham and Miller 125, ID, bottom of Hanson Cr. with Engelmann spruce and subalpine fir, just above Old Boise Trail 101, 6,800', 7/16/80.

Plus 15 Sight Records by Bingham and Miller, C. Johnson, and Steele, Kirkwood Cr. to Landore, 5,000-7,500'.

Anemone multifida Poir. var. *multifida*, Cliff Anemone.

Scarce, central Seven Devils, 7,300' ±.

Bingham and Miller 408, ID and WS, northeast-facing open cliff face, along trail 112 in the head of the east fork of Sheep Cr. ca. ½ mi west-northwest of the Windy Saddle trailhead, 7,350', 8/10/81.

Anemone piperi Britt., Piper's Anemone.

Frequent, entire lower Seven Devils and Rapid River, 5,000-6,800'.

Baker 16798, ID, 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 5/24/65.

Bingham 469, ID, open *Pinus ponderosa-Pseudotsuga menziesii* forest on west-facing slope ca. 0.1 mi northward from Kirkwood Corrals along rd. 420, 5,050', 5/25/82.

C. Johnson 6/29/82, BKR 2326, Plot 790, above the Lost Valley rd. 2060 ca. 100 yds. east of Kirkwood Cr., 5,300', 6/29/82.

Lewis 1286, OGDF, open timber, pass north of Horse Mt., 5,000', 6/10/67.

Plus 10 Sight Records by Bingham and Miller, C. Johnson and Steele, Big Canyon to Huntley Gulch, 5,000-6,800'.

Aquilegia flavescens Wats., Yellow Columbine.

Common, central and southern Seven Devils, 6,700-8,400'.

Baker 12085, ID, steep, rocky bank below Heavens Gate Lookout, 7/21/54.

Bingham and Miller 18, ID, open rocky ridgetop ca. 0.2 mi south-southwest of Heavens Gate Lookout, 8,350', 7/21/79.

*Christ 8643 & 12601, ?NY, lower talus slopes, Pyramid Peak, 8/8/37; and slopes in timber in cirque below Seven Devils Lake, 7/13/41; respectively.

Packard 294, WS, vicinity of Hibbs Cow Camp in the head of the north fork Little Granite Cr., 6,800', 6/26/37.

St. John and Mullen 8515 & 8516, WS, both vicinity of Hibbs Cow Camp, 7/21/27.

Plus 28 Sight Records by Bingham and Miller, C. Johnson and Taylor.

Aquilegia formosa Fisch., Red Columbine.

Uncommon, central and southern Seven Devils, 7,000-8,400'.

Christ 12442, ID, open slopes, Seven Devils, 7,000-8,400'.

*Christ 8647, 12519, & 12579, ?NY, lower talus slopes, Pyramid Peak, 8/8/37; open, grassy east slopes, Heavens Gate, 7/12/41; and cliffs in cirque below Seven Devils Lake, 7/13/41; respectively.

Packard 289, WS, moist shaded wood near left (north) fork of Little Granite Cr., 7,000', 6/13-30/37.

St. John and Mullen 8517, WS, woods near Hibbs Cow Camp, 7,800', 7/21/27.

Clematis columbiana (Nutt.) Torr. and Gray var. *columbiana*, Columbia Clematis.

Frequent, entire Seven Devils, 5,000-7,200'.

Bingham and Miller 184, ID and WS, moderately dense *Pseudotsuga menziesii-Abies lasiocarpa* forest on an east-facing slope ca. 1/2-3/4 mi north of Hanson Cr. along the Old Bois Trail 101, 6,800', 7/18/80.

Comstock 112, WS, rocky, shaded west slope ¼ mi from the top of Lightning-Sheep Cr. ridge, ? elev., 5/12/39.

Moore 87, WS, ¼ mi down the Bernard Cr. trail (110) from McGaffee Cow Camp, 7,500' (prob. nearer 5,500'), 5/16/36.

Packard 292, WS, moist woods near the left (north) fork of

Little Granite Cr., 6,800', 6/26/37.
Plus 12 Sight Records by Bingham and Miller, C. Johnson, and Steele.
Clematis hirsutissima Pursh, Douglas Clematis.
Frequent, entire Seven Devils, 6,500-7,600'.
*Christ 8603, ?NY, timbered mountainside, Placer Basin, 8/8/37.
Christ 12513, ID, open mountainside 1 mi east of Seven Devils Camp, 7/12/41.
Henderson 3856, ID, Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 7/6/77.
Moore 95, WS, ridge southeast of McGaffee Cow Camp, 8,600' (prob. nearer to 6,000'), 5/16/36.
*Nelson and Nelson 2976, ?RM, Dry Diggins Camp, 8/10-15/38.
Ownbey and Meyer 2081, WS, gravelly, exposed ridge, Hibbs Cow Camp, 6/26/40.
St. John and Mullen 8531, WS, gravel slope, Dry Diggins, 7/22/27.
Plus 4 Sight Records by Bingham and Miller and Tisdale.
Clematis ligusticifolia Nutt., Western Clematis.
Scarce, lower Rapid River only, 2,200' +.
Bingham and Miller Sight Record, at the trailhead gate of lower Rapid River trail 113, at the upstream end of the Circle C State Fish Hatchery, 2,200', 6/8/82.
Coptis occidentalis (Nutt.) Torr. and Gray, Western Goldthread.
Occasional, northern and central Seven Devils, 5,000-5,300'.
Baker 16796, ID, 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 5/29/65.
C. Johnson Sight Records: Plot 789, above rd. 2060 ca. ¼ mi east of Kirkwood Cr., 5,220', 6/29/82; and Plot 790, above rd. 2060 just east of Kirkwood Cr., 5,300', 6/29/82.
Delphinium depauperatum Nutt., Dwarf Larkspur.
Uncommon, northern and central Seven Devils, 5,200-7,600'.
Bingham 460, ID, basalt rock ridgetop with sagebrush-grass-forb stand immediately south of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.
*Christ 12451, ?NY, crevices in moist cliffs above Seven Devils Lake, 7/11/41.
Christ 12604, ID and WS, dry creek bed in cirque below Seven Devils Lake, 7/13/41.
*Kruckeberg 3211, ?WTU, rocky ledges and outcrops above Seven Devils Lake, 7/2/52.
LaZelle 4, ID, small meadow just east of Seven Devils Lake, 7,500', 7/29/63.
Packard 444, WS, shaded meadow by small stream near Lily Pad Lake, 7,800', 7/28/38.
Delphinium nuttallianum Pritz. var. *nuttallianum*, Upland Larkspur.
Common, entire Seven Devils and Rapid River, 5,000-8,100'.
Bingham and Miller 52, ID, open, rocky, south-facing slope with scattered subalpine forbs, 250' above and 0.2 mi east of Sheep Lake at the edge of the large-boulderfield at the foot of the long talus slope between Tower of Babel and She Devil Mt., 8,075', 7/23/79.
Christ 12531, WS, open, grassy, east slopes of Heavens Gate, 7/12/41.
Cusick 2230, WS, steep mountainsides, Seven Devils Mts., 7,000', 7/11/1899 (from the elev., date, and previous collections, prob. from along the upper part of the old Kleinschmidt Grade near the Peacock Mine site).
Davis 2404, WS, Papoose Cr. 8 mi southwest of Riggins (prob. along rd. 517 on lower McClinery Ridge), 6/28/40.
C. Johnson 5/25/82, BKR 2208, Plot 717, just southeast of Wild Horse Butte, 5,100', 5/25/82.
Packard 347, WS, pine woods near Seven Devils Guard Station 7/30/37 (possibly the old Seven Devils Guard Station, which was about ¼ mi down the Old Boise Trail 101 from the present guard station).
*Spellenberg 1752, ?WTU, rockslide in ponderosa pine - Douglas-fir forest on the Sheep Rock rd. (106), 6/16/67.

Plus 21 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Delphinium occidentale Wats., Tall Western Delphinium.

Occasional, central and southern Seven Devils, 6,600-7,200'.

Bingham and Miller 263, ID and WS, moist, north-facing slope with a heavy forb cover in an open stand of *Abies lasiocarpa*, in the head of the east fork of Sheep Cr. along trail 112 ca. ½ mi west-northwest of the Windy Saddle trailhead, 7,200', 8/29/80.

*Christ 8599 & 12672, ?NY, open spaces in mixed timber, Placer Basin, 8/8/37; and marshy places in timber on Sheep Cr., 7/17/41; respectively.

Plus 1 Sight Record by Bingham and Miller, also in the east fork of Sheep Cr., 7,100', 8/18/82.

Ranunculus alismaefolius Geyer var. *alismellus* Gray, Dwarf Plaintain-leaved Buttercup.

Uncommon, central and southern Seven Devils, 7,300-7,800'.

Bingham 315, ID and WS, northwest-facing, open, moderately moist sedge meadow in an open *Abies lasiocarpa* forest along the Black Lake rd. 112 ca. ½ mi northeast of High Dive point, 7,550', 7/16/81.

*Christ 8652, ?NY, in timber in cirque on Pyramid Peak, 8/8/37.

Christ 12728, WS, in marsh, Sheep Cr. Swamp, 7/17/41.

*Packard 320, ?WS, moist mountain meadows, "The Swamps" near Lily Pad Lake, 7,800' (actually 7,300'), 6/28/37.

St. John and Mullen 8461, WS, creek bank, Dry Diggins, 7,300', 7/20/27.

Plus 2 Sight Records by Bingham and Miller.

Ranunculus arvensis L., Field Buttercup (European introduction).

Scarce, Rapid River only, 2,200' ±.

Bingham and Miller 449, ID and WS, along the lower Rapid River trail 113 at the Circle C State Fish Hatchery trailhead gate in the southwest end of the Hatchery grounds, *Populus trichocarpa, Crataegus douglasii, Betula occidentalis* riparian type, 2,200', 6/10/82.

?*Ranunculus eschscholtzii* Schlecht. var. *adoneus* (Gray) Hitchc., the twice-lobed and narrow-leaf-segmented variety of the Subalpine Buttercup, (but range of this variety normally Utah and Colorado).

*Christ 12457, ?NY, near snow on cliffs above Seven Devils Lake, 7/11/41.

Ranunculus eschscholtzii Schlecht. var. *suksdorfii* (Gray) Benson, the short-styled, acute-leaf-tipped variety of the Subalpine Buttercup.

Frequent, central and southern Seven Devils, 7,200-8,400'.

Baker 12029, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 7, 75, & 340, ID, & 220, ID and WS, west-facing slope in lee of Snake-Salmon divide ridge, open boulderfield, ca. 0.2 mi southwest of Heavens Gate Lookout, 8,350', 7/21/79; valley bottom bench sedge meadow ca. 2/5 mi directly north of the summit of He Devil Mt., 8,250', 7/25/79; N-facing, half-shaded, rocky hillside in a moderately dense *Abies lasiocarpa* forest along trail 214 ca. 3/4 mi south of Emerald Lake, 7,220', 7/17/81; west-facing, open, wet-soil, luxuriant forb stand recently under snow, in open *Abies lasiocarpa, Pinus albicaulis* stand ca. ¼ mi south of Horse Heaven Lookout cabin, 8,000', 8/25/80; respectively.

*Christ 8635, ?NY, tundra on mountainside, Black Lake, 8/8/37.

Q. Jones 208, ID, vicinity of Heavens Gate Lookout, 7/12/50.

Plus 4 Sight Records by Bingham and Miller.

Ranunculus eschscholtzii Schlecht. var. *trisectus* (Eastw.) Benson, the pubescent-achened, twice-lobed, basal-leaved variety of the Subalpine Buttercup.

Occasional, central Seven Devils, 7,400-8,000'.

Christ 12458, ID, near Seven Devils Lake, 7/11/41.

Ownbey and Meyer 2091, WS, moist soil in *Abies* forest, Hibbs Cow Camp, 6/27/40.

Packard 321, WS, moist mountain meadow, "The Swamps", near Lily Pad Lake, 7,800' (actually nearer 7,300'), 6/28/37.

St. John and Mullen 8533, WS, gravel near snowbank, Dry Diggins, 8,000', 7/22/27.

Ranunculus flamula L., Creeping Buttercup.

Scarce, central Seven Devils, 7,500' ±.

Bingham and Miller 432, ID, bottom of dry, vernal pond along trail 123 ca. 0.1 mi east of Basin Lake, 8/13/81.

Plus 1 Bingham and Miller Sight Record, bottom of vernal pond between He Devil and Triangle Lakes, along trail 129, 7,500', 8/14/81.

Ranunculus glaberrimus Hook. var. undet., Sagebrush Buttercup.

Scarce (mostly at lower elevs.), northern Seven Devils, 5,000-5,400'.

Bingham and Miller Sight Record, along trail 104 on the Deer-Big Canyon Crs. Ridge ca. 1 mi north of Big Canyon Saddle, 5,400', 6/11/82.

*Packard 588, ?WS, Low Saddle, Snake River Canyon, 5,350', 5/13/39.

Ranunculus uncinatus D. Don var. *parviflorus* (Torr.) Benson, Little Buttercup.

Frequent, entire Seven Devils and west fork Rapid River, 5,000-7,900'.

Bingham and Miller 591, ID, in the creekbottom of a clearcut of an east-facing, *Pseudotsuga menziesii*, *Pinus ponderosa*, *Abies grandis* stand along rd. 517 ca. ½ mi above its 2d crossing of Papoose Cr. in sec. 16, 4,900', 8/17/82.

Plus 10 Sight Records by Bingham and Miller and Steele: from Meyer Cr. along rd. 2060 to shores of Black Lake, 5,800-7,900'.

Thalictrum occidentale Gray, Western Meadowrue.

Abundant, entire Seven Devils and Rapid River, 5,000-7,600'.

Baker 12088 & 16794, ID, steep rocky bluffs below Heavens Gate, 7/21/54; and 9 mi west of Riggins (prob. on McClinery Ridge along rd. 517), 5/24/65; respectively.

Bingham and Miller 161, ID and WS, streambank opening along a gently east-facing stream bottom 3/4-shaded by an *Abies lasiocarpa-Picea engelmannii* forest, just below the Old Boise Trail at Hanson Cr., 6,700', 7/17/80.

Christ 12602, ID and WS, along creek in cirque below Seven Devils Lake, 7/13/41.

Lewis 2269a, BOIS, OGDF, near Steele Stands 24 and 25, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,700', 6/12/72.

Packard 328, WS, open pine woods near McGaffee Cow Camp, 5,400', 6/29/37.

Plus 55 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Lockwood Saddle, 5,000-7,600'.

Trollius laxus Salisb. var. *albiflorus* Gray, the white-flowered, western variety of Globeflower.

Frequent, central and southern Seven Devils, 6,600-7,300'.

Bingham 338 & Bingham and Miller 397, ID and WS, gently north-northwest-facing, half-open streambottom under an *Abies lasiocarpa-Pinus albicaulis* stand, along trail 214 ca. ½ mi north of Purgatory Saddle, 7,620', 7/17/81; and on a 2/3-shaded marshy bench in the perched marsh along Bridge Cr. ca. ½ mi below Mirror Lake, 7,300', 7/26/81; respectively.

C. Johnson 8/31/83, BKR 2580, Plot 7069, west of the Deep Cr. trail 219 ca. ½ mi west of the Black Lake rd. 112, *Deschampsia caespitosa* meadow community, 6,760', 8/31/83.

Packard 319, WS, moist mountain meadow, "The Swamps" near Lily Pad Lake, 7,800' (actually nearer 7,300'), 6/28/37.

St. John and Mullen 8500, WS, creek bank, Dry Diggins Area, 7,300', 7/20/27.

Plus 8 Sight Records by Bingham and Miller, Bernard Lakes and Dry Diggins Ridge south to Ruth Lake, 6,600-7,300'.

Rhamnaceae

Ceanothus sanguineus Pursh, Redstem Ceanothus.

Scarce (mostly at lower elevs.), central Seven Devils, 5,000' ±.

Bingham and Miller 565, ID and WS, moderately open, southeast-facing, rocky hillside in Douglas-fir/ninebark h.t. along rd. 517 on lower McClinery Ridge ca. 1 mi above its 2d crossing of Papoose Cr. in sec. 26, 5,150', 8/17/82.

Ceanothus velutinus Dougl. var. *velutinus*, Sticky Buckbrush.

Frequent, entire Seven Devils and upper Rapid River, 5,000-7,300'.

Baird 8/1/71, Council R.D., ¼ way down Bear-Landore rd. (105) 5,200', 8/1/71.

Bingham and Miller 186, ID and WS, in an open Douglas-fir forest on a rocky, east-facing slope ca. 1/2-3/4 mi north of Hanson Cr. along the Old Boise Trail 101, 6,800', 7/18/80.

*Nelson and Nelson 2969, ?RM, Dry Diggins Camp, 8/10-15/38.

St. John and Mullen 8487, WS, open rocky slope, Dry Diggins Area, 7/20/27.

Plus 8 Sight Records by Bingham and Miller and Steele, east fork of Sheep Cr. to Landore-Lockwood Saddle area, 5,300-7,000'.

Rhamnus purshiana DC., Cascara.

Scarce, Rapid River only, 2,400-3,200'.

Bingham and Miller Sight Records: along the lower Rapid River trail 113 ca. ¼ mi above Blue Gulch, 2,400', 6/8/82; and along the west fork Rapid River trail 113 near trail 60, 3,200', 6/9/82.

Rosaceae

Amelanchier alnifolia Nutt. (The several varieties are considered poorly defined and are intergradient in the Seven Devils, so are not used here).

Abundant, entire Seven Devils, 5,000-7,600' and Rapid River.

Bingham and Miller 109, ID and WS, open *Pinus contorta* forest with shrub-forb stand, just across the north fork of Bridge Cr. directly north of Seven Devils Guard Station, 7,300', 7/14/80.

Brewer 6/27/29, IDF 83017, open woodland with pine and bunchgrass, Weiser (now Payette) National Forest, 5,500', 6/27/29.

*Christ 11068, ?NY, mountainside in Snake River Gorge west of Cuprum, ? elev., 5/30/40.

*Meyer 854, ?WS, 2½ mi above the Snake River in Bernard Cr., ? elev., 5/13/37.

Plus 39 Sight Records by Bingham and Miller, C. Johnson and Steele, Big Canyon Saddle to Lockwood Saddle, 5,000-7,600'.

Cercocarpus ledifolius Nutt. var. *intercedens* Schneid., the variety of Mountain Mahogany with incurved leaf margins.

Frequent, low elevs. entire Seven Devils and Rapid River, 5,000-7,000

*Baker 11302, ?ID, high, jagged rocks, Sheep Rock (north end of rd. 106), 9/3/53.

Bingham 269, ID and WS, rocky, open grassland at Sawpit Saddle, 5,050', 7/8/81.

Comstock 108, WS, on very rocky, dry soil near peak of ridges between Sheep and Lightning Crs., 6,000', 5/12/39.

Meyer 1617, WS, bare cliffs above the east side of Sheep Cr. 2 mi above the Snake River, 5,000', 5/12/39.

Moore 77, WS, McGaffee Cow Camp, head of Bernard Cr., 7,000' (actually the Camp is at 5,700'), 5/16/36.

St. John and Mullen 8495, WS, small trees on rocky ledges, Dry Diggins, head of Bernard Cr., 7,000', 7/20/27.

Plus 4 Sight Records by Bingham and Miller and C. Johnson.

Crataegus douglasii Lindl. var. *douglasii*, the Rocky Mountain variety of Black Hawthorne.

Uncommon (mostly at lower elevs.), entire Seven Devils and Rapid Rive 5,000-5,400'.

Bingham 535, ID, open, clearcut plantation area near ridgetop, along rd. 420 ca. 0.2 mi south of rd. 241 and 1½ mi south of Cow Cr. Saddle, 5,400', 7/21/82.

Plus 4 Sight Records by Bingham and Miller, below Big Canyon Saddle, north of Cow Cr. Saddle, and in Rapid River, 2,200-5,200'.

Fragaria vesca L. var. *bracteata* (Heller) Davis, the long-peduncled variety of the Woods Strawberry.

Common, entire Seven Devils and Rapid River, 5,000-7,800'.

Bingham and Miller 126, ID and WS, open, southeast-facing slope in a *Pinus contorta-Abies lasiocarpa* stand along the Old Boise Trail ca. 0.1 mi north of Hanson Cr., 6,800', 7/16/80.

Brewer 52, Council R.D., Fawn Cr., sec. 8, T. 19 N., R. 2 W., 5,000', 6/11/29.

Comstock 91, WS, north slope of Lightning Cr. 6 mi from Snake River, ? elev., 5/13/39.

Moore 93, WS, head of Bernard Cr., McGaffee Cow Camp, 8,600' (the Camp is at 5,700'), 5/16/36.

Plus 36 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Lockwood Saddle and Landore, 5,000-7,800'.

Geum macrophyllum Willd. var. *perincisum* (Rydb.) Raup, the variety of Large-leaved Avens from east of the Cascade Mountains.

Occasional, central Seven Devils, 6,600-7,400'.

Baker 12273, ID, moist ground, streamside, west slope of Heavens Gate (possibly in a south fork of the east fork of Sheep Cr. below the spring for the old Windy Saddle campground ca. ¼ mi northwest of the Saddle), 7/31/54.

Bingham and Miller Sight Records: shores of Baldy Lake, 7,200', 8/15/81; along Horse Heaven Cr. just west of the Old Boise Trail, 7,100', 8/18/81; and along trail 124 ca. 1 mi northwest of Baldy Lake, 6,600', 8/14/81.

Geum triflorum Pursh var. *ciliatum* (Pursh) Fassett, the east Rocky Mountains variety of Prairie Avens.

Common, entire Seven Devils and Rapid River, 5,000-7,700'.

Baird 8/1/71, Council R.D., Summit Cr. rd., 5,500', 8/1/71.

Baker 12037, ID, open alpine slope, Seven Devils Camp, 7/21/54.

Bingham 541, ID and WS, open sedge-forb meadow on ridgetop with basaltic rock, ca. 0.1 mi south of Cow Cr. Saddle, 5,240', 7/21/82.

*Christ 12573, ?NY, grassy west slopes, Heavens Gate, 7/12/41.

Jones 225, ID and WS, grassy meadow, Heavens Gate, 7/13/50.

Moore 96, WS, ridge southeast of McGaffee Cow Camp, 8,600' (prob. nearer to 6,000'), 5/16/36.

Packard 582, WS, under open pine stand in Low Saddle, 5,350', 5/13/39.

Plus 17 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Holodiscus discolor (Pursh) Maxim., Creambush Ocean Spray.

Common, low elevs., entire Seven Devils and Rapid River, 5,000-7,000'.

Baird 8/18/71, Council R.D., on small creek 1 mi above Bear Guard Station, 5,200', 8/18/71.

Baker 11337, ID, open, wooded thicket 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Brewer 74, Council R.D., Rapid River bridge, mouth of Paradise Cr. (apparently the trail 181 bridge), 4,500', 7/31/29.

Holmgren and Tillett 9609, WS, road between Cuprum and the Snake River, ? elev., 7/14/53.

*Nelson and Nelson 3003, ?RM, trail to Dry Diggins, 8/10-15/38.

Plus 18 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to Rankin Mill, 5,000-7,000'.

Physocarpus malvaceus (Greene) Kuntze, Mallow Ninebark.

Common, entire Seven Devils and Rapid River, 5,000-6,800'.

Bingham and Miller 179, ID and WS, east-facing, 1/3-shaded, rocky slope in a *Pseudotsuga menziesii/Physocarpus malvaceus* h.t. along the Old Boise Trail 101 ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

Christ 12628, ID and WS, timbered mountainside with Douglas-fir on the trail from the Wilson (Hibbs) Cow Camp (trail 124) to Baldy Lake, 7/15/41.

*Nelson and Nelson 3013, ?RM, Dry Diggins trail, 8/10-15/38.

Plus 22 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Huntley Gulch, 5,000-6,700'.

Potentilla arguta Pursh var. *convallaria* (Rydb.) Wolf, Valley Cinquefoil.

Occasional, central Seven Devils, 6,500-7,700'.

Baker 12076, ID, dry, rocky hillside above Seven Devils Guard Station, 7/21/54.

Christ 12507, ID, open, grassy mountainside 1 mi east of Seven Devils Camp, 7/12/41.

C. Johnson 8/14/83, BKR 2484, Plot 7036, east of the Old Boise Trail 101 along the Snake-Salmon Rivers divide ca. 0.2 mi south of where trail 110 turns east and down the south fork of Squaw Cr., *Festuca idahoensis-Koeleria cristata* community, 7,660', 8/14/83.

Plus 1 Sight Record by C. Johnson Plot 7034, Old Timer Mine, 6,470', 8/13/83.

Potentilla diversifolia Lehm. var. *diversifolia*, Varileaved Cinquefoil.

Occasional, central and southern Seven Devils, 7,200-8,400'.

Bingham and Miller 76, ID, gently sloping, north-facing, open, wet, dense, low-sedge meadow bordered by an open *Abies lasiocarpa-Pinus albicaulis* forest, ca. 0.4 mi almost directly north of the summit of He Devil Mt. in the valley southwest of trail 123, 8,300', 7/25/79.

Christ 8640, WS, lakeshore, Black Lake, 8/8/37.

*Christ 12543, ?NY, in tundra on peak, Heavens Gate, 7/12/41.

Tisdale Sight Record, vicinity of Bald Mt., 7,700', 7/16/79.

Potentilla flabellifolia Hook., Fanleaved Cinquefoil.

Frequent, central and southern Seven Devils, 7,000-8,000'.

Baird 7/29/71, Council R.D., base of talus slope ¼ mi north of High Dive, 7,500', 7/29/71.

Bingham and Miller 32 & 316, ID, in an open sedge bog at the north end of the pond along the northeast side of Sheep Lake, 7,880', 7/22/79; and moist, northwest-facing, stabilized talus under a dense sedge mat at the foot of a cirque wall, ca. ½ mi easterly along rd. 112 from High Dive point, 7,550', 7/16/81; respectively.

*Christ 8650, ?NY, in timber in cirque on Pyramid Peak, 8/8/37.

Christ 12609, ID and WS, banks of Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41.

Davis 2531, WS, moist ravine, Black Lake, 7/3/40.

St. John and Mullen 8528, WS, in meadow at Dry Diggins, 8,000', 7/22/27.

Plus 10 Sight Records by Bingham and Miller.

Potentilla glandulosa Lindl. var. *glandulosa*, Glandular Cinquefoil.

Scarce, central Seven Devils, 7,600' ±.

Baker 12038, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Potentilla glandulosa Lindl. var. *intermedia* (Rydb.) Hitchc., the subrotate-calyxed, long- and dark-yellow-petaled variety of the Glandular Cinquefoil.

Common, entire Seven Devils, 5,900-8,000'.

Bingham and Miller 147, ID, southeast-facing, gentle, open, rocky slope with a sedge-forb meadow in an open *Pinus contorta-Abies lasiocarpa* forest, along the Old Boise Trail 101 ca. 0.1 mi northeast of Hanson Cr., 6,800', 7/17/80.

Q. Jones 200, ID, among rocks on south-facing slopes, Heavens Gate, 7/12/50.

Plus 30 Sight Records by Bingham and Miller (Low Saddle to Lockwood Saddle, 5,900-8,000').

Potentilla glandulosa Lindl. var. *pseudorupestris* (Rydb.) Breit., the subrotate-calyxed and long- but light-yellow-to-white-petaled variety of the Glandular Cinquefoil.

Uncommon, entire Seven Devils, 8,000-9,300'.

Bingham and Miller 44, ID, bedrock crevices on open, bedrock ridgetop, summit of She Devil Mt., 9,300', 7/23/79.

*Christ 8674 & 8710, ?NY, talus slopes near Black Lake, 8/8/37; and slopes of high ridges near Black Lake, 8/8/37; respectively.

Comstock 93, WS, 6 mi from the Snake River on the ridge between Lightning and Sheep Cr., ? elev., 5/12/39.

*Nelson and Nelson 2990 & 3011, ?RM, Horse Heaven and Dry Diggins, respectively, 8/10-15/38.

St. John and Mullen 8509, WS, rocky cliffs, Dry Diggins, 8,000', 7/21/27.

Potentilla glandulosa Lindl. var. undet., Glandular Cinquefoil.

Christ 12473, WS, cliffs on Seven Devils Ridge, 7/11/41 (identification in question, teste S. Saufferer).

*Christ 12503, ?NY, open, grassy slopes, Seven Devils Camp, 7/12/41.

Plus 18 Sight Records by C. Johnson and Steele.

Potentilla gracilis Dougl. var. *brunescens* (Rydb.) Hitchc., the glandular and pubescent variety of Slender Cinquefoil.

Scarce, northern Seven Devils, 5,000' ±.

Packard 578, WS, exposed, grassy slope above the Clark's Fk. of Sheep Cr., ? elev., 5/13/39.

Potentilla gracilis Dougl. var. *flabelliformis* (Lehm.) Nutt., the variety of Slender Cinquefoil having deeply dissected leaves.

Scarce, central and southern Seven Devils, 6,200-6,800'.

point, 7,550', 7/16/81; respectively.

*Christ 8650, ?NY, in timber in cirque on Pyramid Peak, 8/8/37.

Christ 12609, ID and WS, banks of Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41.

Davis 2531, WS, moist ravine, Black Lake, 7/3/40.

St. John and Mullen 8528, WS, in meadow at Dry Diggins, 8,000', 7/22/27.

Plus 10 Sight Records by Bingham and Miller.

Potentilla glandulosa Lindl. var. *glandulosa*, Glandular Cinquefoil.

Scarce, central Seven Devils, 7,600' ±.

Baker 12038, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Potentilla glandulosa Lindl. var. *intermedia* (Rydb.) Hitchc., the subrotate-calyxed, long- and dark-yellow-petaled variety of the Glandular Cinquefoil.

Common, entire Seven Devils, 5,900-8,000'.

Bingham and Miller 147, ID, southeast-facing, gentle, open, rocky slope with a sedge-forb meadow in an open *Pinus contorta-Abies lasiocarpa* forest, along the Old Boise Trail 101 ca. 0.1 mi northeast of Hanson Cr., 6,800', 7/17/80.

Q. Jones 200, ID, among rocks on south-facing slopes, Heavens Gate, 7/12/50.

Plus 30 Sight Records by Bingham and Miller (Low Saddle to Lockwood Saddle, 5,900-8,000').

Potentilla glandulosa Lindl. var. *pseudorupestris* (Rydb.) Breit., the subrotate-calyxed and long- but light-yellow-to-white-petaled variety of the Glandular Cinquefoil.

Uncommon, entire Seven Devils, 8,000-9,300'.

Bingham and Miller 44, ID, bedrock crevices on open, bedrock ridgetop, summit of She Devil Mt., 9,300', 7/23/79.

*Christ 8674 & 8710, ?NY, talus slopes near Black Lake, 8/8/37; and slopes of high ridges near Black Lake, 8/8/37; respectively.

Comstock 93, WS, 6 mi from the Snake River on the ridge between Lightning and Sheep Cr., ? elev., 5/12/39.

*Nelson and Nelson 2990 & 3011, ?RM, Horse Heaven and Dry Diggins, respectively, 8/10-15/38.

St. John and Mullen 8509, WS, rocky cliffs, Dry Diggins, 8,000', 7/21/27.

Potentilla glandulosa Lindl. var. undet., Glandular Cinquefoil.

Christ 12473, WS, cliffs on Seven Devils Ridge, 7/11/41 (identification in question, teste S. Saufferer).

*Christ 12503, ?NY, open, grassy slopes, Seven Devils Camp, 7/12/41.

Plus 18 Sight Records by C. Johnson and Steele.

Potentilla gracilis Dougl. var. *brunescens* (Rydb.) Hitchc., the glandular and pubescent variety of Slender Cinquefoil.

Scarce, northern Seven Devils, 5,000' ±.

Packard 578, WS, exposed, grassy slope above the Clark's Fk. of Sheep Cr., ? elev., 5/13/39.

Potentilla gracilis Dougl. var. *flabelliformis* (Lehm.) Nutt., the variety of Slender Cinquefoil having deeply dissected leaves.

Scarce, central and southern Seven Devils, 6,200-6,800'.

Baker 11326, ID, moist ground about spring, 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham and Miller 438, ID, east-facing, open, meadowy hillside, an open meadow bordered by a moderately dense *Picea engelmannii, Abies lasiocarpa, Pinus contorta* forest, Old Town (old mining camp) ca. ¼ mi south of Rankin Mill in the west fork of the Rapid River at the jct. of trails 191 and 113, 6,160', 8/16/81.

Potentilla gracilis Dougl. var. *glabrata* (Lehm.) Hitchc., the variety of Slender Cinquefoil having less deeply dissected as well as greenish-undersided leaves.

Uncommon, northern and central Seven Devils, 5,000-8,000'.

Aldrich 7/4/07, ID 2701, Camp Howard, 5,000' (prob. the Cow Camp), 7/4/07.

Baker 12014, ID, open alpine slopes at Seven Devils Camp, 7/21/54.

Christ 12504, ID and WS, grassy slopes, Seven Devils Camp, 7/12/41.

Davis 2353, IDF and WS, medium dry open hill, Heavens Gate, 6/28/40.

Packard 431 & 578, WS, dry open flat, Hibbs Cow Camp, 8,000', 7/26/38; and exposed, grassy slope above the Clark's Fk. of Sheep Cr., ? elev., 5/13/39; respectively.

Potentilla gracilis Dougl. var. undet., Slender Cinquefoil.

Baird 6/26/72, Council R.D., 2 mi below Placer Basin Mine, 5,000', 6/26/72.

Bingham and Miller Sight Records: Grave Point to Landore, and Rapid River, 5,400-7,000', 7 records.

C. Johnson Sight Records: Dixon Corrals to Horse Heaven Lookout pasture, 5,150-8,050', 4 records.

*Kruckeberg 3191, ?WTU, open, grassy hillside above Seven Devils Forest Station (the Guard Station), 7,000' (must be above 7,200'), 7/30/52.

Prunus emarginata (Dougl.) Walp. var. *emarginata*, Bitter Cherry.

Frequent, entire Seven Devils, 5,000-7,000'.

Bingham 288, ID, east-facing, open, moderately dry, rocky hillside, surrounded by a moderately open *Pseudotsuga menziesii-Pinus contorta* forest, along the Old Boise Trail 101 on the Snake-Salmon Rivers divide ca. ½ mi northeast of its jct. with the Lightning Cr. Ridge trail 52, 6,760', 7/9/81.

*Christ 11069, ?NY, mountainside in Snake River Gorge west of Cuprum, 5/30/40.

Moore 71, WS, rocky hillside, Bernard Cr. trail (110), 3 mi from Snake River, 5,000', 5/16/36.

St. John and Mullen 8514, WS, woods at Hibbs Cow Camp, 8,000', 7/21/27.

Plus 7 Sight Records by Bingham and Miller, Big Canyon Saddle to Lockwood Saddle, 5,000-7,000'.

?*Prunus virginiana* L. var. *demissa* (Nutt.) Torr., the black-fruited variety of the Common Chokecherry, (but out of the western Cascade range of var. *demissa*).

*Christ 11063, ?NY, on high slopes overlooking the Snake River Gorge west of Cuprum, ? elev., 5/30/40.

Prunus virginiana L. var. *melanocarpa* (Nels.) Sarg., the dark-blue-purple-fruited variety of the Common Chokecherry.

Uncommon (mostly from lower elevs.), entire Seven Devils and Rapid River, 5,000-6,500'.

Bingham and Miller 582, ID and WS, amongst roadside brush along rd. 517 ca. ¼ mi up the rd. from its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Brewer 58, Council R.D., Krammer Cabins, sec. 1, T. 20 N., R. 3 W., (prob. along rd. 105), 5,000', 6/21/29.

Comstock 106, WS, north slope of Lightning Cr. 10 mi from Snake River, ? elev., 5/12/39.

Plus 5 Sight Records by Bingham and Miller, C. Johnson, and Steele, north of Emerald Lake to Bear-Indian Crs. divide along rd. 002, 5,000-6,450'.

Purshia tridentata (Pursh) DC., Bitterbrush.

Scarce (mostly at lower elevs.), southern Seven Devils, 5,000' ±.

*Christ 8590, ?NY, on basalt scabland 6 mi north of Bear (prob. along rd. 105), 8/8/37.

Rosa gymnocarpa Nutt., Little Wild Rose.

Frequent, entire Seven Devils, 5,100-7,100'.

C. Johnson Sight Records, Wild Horse Butte and Motthorn Saddle south to Carbonate Hill, 5,100-7,000', 6 records.

St. John and Mullen 8392, WS, thickets at McGaffee Cow Camp, 6,000', 7/17/27.

Steele Sight Records, Papoose Cr. south to 6 mi north of Cuprum, 5,500-5,800', 3 records.

Rosa nutkana Presl var. *hispida* Fern., Bristly Nootka Rose.

Occasional, central and southern Seven Devils, 5,000-7,100'.

Bingham and Miller 572, ID and WS, along the upper side of rd. 517 on a southeast-facing, open, rocky but grass-sedge-forb covered slope ca. ¼ mi above the crossing of Shingle Cr., 7,100', 8/17/82.

*Christ 11067, ?NY, on mountainsides in Snake River Gorge west of Cuprum, 5/30/40.

Steele Sight Record, Stand 81-Pa-01B, along the Indian Cr. rd. 105, 6 mi above Cuprum, 5,550', 6/24/81.

Rosa woodsii Lindl. var. *ultramontana* (Wats.) Jeps., Pearhip Rose.

Occasional (mostly from lower elevs.), central and southern Seven Devils, 5,000-6,000'.

Packard 266, WS, open flat on Timbered Bench above Little Granite Cr., 6,000', 6/20/37.

Steele Sight Records: Stand 72-Pa-24, along the Bear-Cuprum rd. 002 above Huntley Gulch, 5,000', 6/12/72; and Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,100', 6/12/72.

Rubus discolor Weihe and Ness, Himalayan Blackberry (Old-World introduction).

Scarce, Rapid River only, 4,000' minus.

Bingham and Miller Sight Record, in McCrea Cr. at the McCrea Place, 4,000', 6/9/82.

Rubus idaeus L. var. *gracilipes* Jones, the woolly-leaved variety of Red Raspberry.

Common, central and southern Seven Devils, 6,600-8,400'.

Bingham and Miller 185, ID and WS, northeast-facing, open, loose rockslide along the Old Boise Trail 101 ca. 0.1 mi southward from Cannon Cr., 6,600', 7/18/80.

*Christ 12677, ?NY, in slide rock on Sheep Cr. trail (112), 7/17/41.

F. Johnson 8/16/62 & 6/25/64, IDF 6225 & 697231, among rocks in exposed area, Heavens Gate, 7,500', 8/16/62; and among rocks, open faces, Heavens Gate Lookout, 6/25/64; respectively.

Meyer 257, WS, on rock tables and outcroppings, Seven Devils Mts. above Sheep Cr. and the Snake River Canyon, 5/16/36.

St. John and Mullen 8448, WS, woody crest of Dry Diggins, 7,500', 7/20/27.

Plus 18 Sight Records by Bingham and Miller, Bald Mt. to Smith Mt., 6,800-8,000'.

Rubus leucodermis Dougl., Black Raspberry.

Scarce (mostly at lower elevs.), central Seven Devils and Rapid River, 5,000' ±.

Bingham and Miller 568, ID, east-facing, open creek bottom in a clearcut stand of *Pinus ponderosa*, *Pseudotsuga menziesii*, and *Abies grandis*, in the northmost fork of Shingle Cr. traversed by rd. 517 ca. ½ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,900', 8/17/82.

Plus 2 Sight Records by Bingham and Miller, lower Rapid River and west fork Rapid River, 2,600-3,600'.

Rubus parviflorus Nutt., Thimbleberry.

Common, entire Seven Devils and Rapid River, 5,000-7,200'.

Baker 12257, ID, moist woods along Shingle Cr. (prob. along rd. 517), 7/31/54.

Brewer 147, IDF 77115, Rapid River, sec. 10, T. 22 N., R. 1 W., 4,000', 8/26/31 (prob. along trail 177 near Hall or Castle Cr.).

*Christ 8620 & 12689, ?NY, springy places on mountainside, Black Lake, 8/8/37; and timbered mountainside along the Sheep Cr. trail (112), 7/17/41; respectively.

Plus 25 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle south to Lockwood Saddle, and lower Rapid River, 5,000-7,200'.

Sibbaldia procumbens L., Creeping Sibbaldia.

Common, central and southern Seven Devils, 6,800-9,000'.

Baker 11304, ID, moist, shaded slope, Sheep Rock, 9/3/53.

Bingham and Miller 25, ID, west-facing, small, rocky sedge meadow in an open *Abies lasiocarpa-Pinus albicaulis* stand ca. 0.1 mi southwest of Heavens Gate Lookout, 8,300', 7/25/79.

*Christ 8670, 12455, & 12554, ?NY, rocky talus slopes on Pyramid Peak, 8/8/37; in tundra on grassy slopes by Seven Devils Lake, 7/11/41; and on rocky shingle of ridge, Heavens Gate, 7/12/41; respectively.

St. John and Mullen 8557, WS, rocky ledge on He Devil Mt., 9,000', 7/24/27.

Plus 15 Sight Records by Bingham and Miller, trail 112 between the forks of Sheep Cr. to Purgatory Saddle and Black Lake, 7,000-8,200'.

Sorbus scopulina Greene var. *scopulina*, Cascade Mountain Ash.

Common, entire Seven Devils and west fork Rapid River, 5,300-7,000'.

Baird 6/26/72, Council R.D., 2 mi below Placer Basin Mine, 5,000', 6/26/72.

Bingham and Miller 400, ID, northeast-facing, half-shaded, rocky slope in an open *Abies lasiocarpa-Pinus contorta* forest ca. ¼ mi south-southwest of Seven Devils Guard Station in the dry fork of Bridge Cr. below Seven Devils Lake, 7,300', 7/26/81.

Brewer 32, IDF, Patrolman Cr., sec. 1, T. 22 N., R. 2 W., 6,000' (small side drainage running into the west fork of the Rapid River north of Jackley Mt.), 8/30/28.

*Nelson and Nelson 2960, ?RM, Rapid River Trail (number unknown), 8/10-15/38.

Plus 25 Sight Records by Bingham and Miller, C. Johnson, and Steele, Cow Cr. Saddle to Lockwood Saddle, 5,300-7,000', and west fork Rapid River.

?*Sorbus sitchensis* Roem. var. *sitchensis*, Sitka Mountain Ash.

*Christ 12681, ?NY, with Douglas-fir along the Sheep Cr. trail 112, 7/17/41 (but *S. sitchensis* normally is only a northern Idaho species; prob. this collection is *S. scopulina*, as found by Bingham and Miller along trail 112 in the west fork of Sheep Cr., and seen elsewhere along trail 112).

Spiraea betulifolia Pall. var. *lucida* (Dougl.) Hitchc., the white-flowered variety of the Shiny-leaf Spiraea.

Common, entire Seven Devils and Rapid River, 5,000-7,500'.

Baker 11336, ID, open, wooded thicket 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham and Miller 249, ID and WS, north-facing, half-shaded, rocky slope in a moderately dry and dense *Pinus contorta, Picea engelmannii, Abies lasiocarpa* forest, along trail 189 ca. ½ mi north of the Ruth Lake trail, 7,000', 8/27/80.

*Christ 8595, ?NY, timbered mountainside 6 mi north of Bear, 8/8/37.

*Nelson and Nelson 3012, ?RM, Dry Diggins, 8/10-15/38.

Plus 35 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Lockwood Saddle, 5,000-7,500', and lower west fork of Rapid River.

Spiraea densiflora Nutt. var. *densiflora*, Subalpine Spiraea.

Frequent, central and southern Seven Devils, 7,200-8,500'.

Bingham 327 & Bingham and Miller 372, ID and WS, open lakeshore with a deep, gravelly-silty loam soil at the edge of a moderately dense *Abies lasiocarpa-Picea engelmannii* forest, along the northwest shore of Black Lake, 7,200', 7/17/81; and open stream bottom with a deep silty loam soil at the outlet of Lower Cannon Lake, edge of an *Abies lasiocarpa, Picea engelmannii, Pinus contorta* forest, 7,000', 7/27/81; respectively.

*Christ 8697, ?NY, high slopes near Black Lake, 8/8/37.

Kruckeberg 3212, WS and WTU, at borders of Seven Devils Lake, 8/2/52.

LaZelle 8/28/63, ID 44475, east shore of Seven Devils Lake, 8/28/63.

St. John and Mullen 8556, WS, shores of "Little Granite Cr. Lake" (prob. in the head of the Echo Lake chain), 8,500', 7/24/27.

Plus 5 Sight Records by Bingham and Miller, shores of Echo, Lily Pad Basin and northeasternmost of lakes in Six Lake Basin, and shores of pond ¼ mi south of Purgatory Saddle, 7,200-7,600'.

Rubiaceae

Galium aparine L. var. *echinospermum* (Wallr.) Farw., the variety of Goosegrass Bedstraw having fruits with hooked spines.

Frequent, entire Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller 193, east-facing, rocky slope in *Pseudotsuga menziesii* forest along the Old Boise Trail ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

*Christ 8629, ?NY, springy places on mountainside, Black Lake, 8/8/37.

Plus 17 Sight Records by Bingham and Miller, C. Johnson, Steele, and Tisdale, Big Canyon Saddle to Emerald Lake, 5,000-7,600'; also Rapid River.

Galium bifolium Wats., Low Mountain Bedstraw.

Frequent, entire Seven Devils, 5,000-7,500' +.

Bingham and Miller 142, ID, and 512, ID and WS, rocky, east-facing, sedge-forb meadow along edge of boulderfield along the south side of Dog Cr. ca. 3/5 mi below Dog Lake, 7,500', 7/16/80; and rocky, granitic soil on south-facing roadbank along rd. 106 ca. 1 mi north of Lockwood Saddle, 6,700', 5/30/82; respectively.

*Christ 12530, ?NY, thin soil on open east slopes, Heavens Gate, 7/12/41.

Davis 2344, ID and WS, moderately dry, open hillsides, Sheep Cr., 6/26/40.

Ownbey and Meyer 2070, WS, gravel slide, headwaters of Sheep Cr., 6/26/40.

Plus 5 Sight Records by Bingham and Miller and Steele, Cold Springs Lookout site to Huntley Gulch, 5,000-7,300'.

Galium multiflorum Kell., Many-flowered Bedstraw.

Scarce, southern Seven Devils, 5,000' ±.

Christ 11072, ID and WS, mountainside in Snake River Gorge west of Cuprum, 5/30/40.

Galium triflorum Michx., Sweet-scented Bedstraw.

Uncommon, entire Seven Devils, 5,000-6,700'.

Baird 8/6/71, Council R.D., in timber along Landore-Cuprum rd. ½ mi from Cuprum, 5,000', 8/6/71.

Baker 12261, ID, moist woods along Shingle Cr. (prob. the north fork along rd. 517), 7/31/54.

C. Johnson Sight Records: Plot 789, along rd. 2060 ca. ¼ mi east of Kirkwood Cr., 5,220', 6/29/82; Plot 7019, ca. 1¼ mi west of Echo Lake below trail 124, 6,610', 8/11/83; Plot 7029, west of trail 110 on the Bills-Sheep Cr. divide ca. ½ mi north of trail 140, 5,600', 8/13/83; and Plot 7056, along the Old Boise Trail 101 ca. ¼ mi southwest of Cannon Cr., 6,720', 8/21/83.

Steele Sight Records, Stand 74-38, along rd. 517 below the south fork of Papoose Cr., 5,800', 8/8/74; and stand 81-Pa-01B, along Indian Cr. rd. 105 ca. 6 mi above Cuprum, 5,500', 6/24/81.

Kellogia gallioides Torr., Kellogia.

Scarce, central Seven Devils, 6,800-7,200' ±.

Christ 12701, ID and WS, slide rock on west slopes along Sheep Cr. trail (112), 7/17/41.

Packard 456, WS, moist shady places near streambank where the Brundage Trail crosses the west fork of Sheep Cr. (trail 112), 6,700', 7/28/38.

Salicaceae

Populus tremuloides Michx., Trembling or Quaking Aspen.

Common, entire Seven Devils, 5,200-7,300'.

Baker 12093, ID, rocky canyon below Heavens Gate, 7/21/54.

St. John and Mullen 8393, WS, thicket, McGaffee Cow Camp, 5,400', 7/17/27.

Plus 18 Sight Records by Bingham and Miller and C. Johnson, (Cow Cr. Saddle, to Cuprum-Landore rd. 105, 5,200-7,300').

Populus trichocarpa Torr. and Gray, Northern Black Cottonwood.

Scarce, southern Seven Devils and Rapid River, 5,300' ±.

Bingham and Miller Sight Records: at old Landore where rd. 105 crosses Indian Cr., 5,350', 6/30/82; and at the trail 113 trailhead gate at the southwest end of the Circle C State Fish Hatchery, 2,200', 6/8/82, and along the west fork Rapid River trail 113 ca. ¼ mi west of the main forks in sec. 26, 2,800', 6/8/82.

?*Salix boothii* Dorn, Booth's Willow.

Scarce, central and southern Seven Devils, 7,400-7,600' ±.

Bingham and Miller 229 & 350, ID and WS, west bank of Horse Heaven Lake, 7,600', 8/26/80; and at the outlet of the largest and northeasternmost of the lakes in Six Lake Basin, 7,440', 7/18/81; respectively (but only male catkins were collected, and females are needed for positive identification).

Salix commutata Bebb, Undergreen Willow.

Scarce, central Seven Devils, 7,100' ±.

Bingham and Miller 260, ID and WS, bank of the easternmost of the Bernard Lakes along trail 57, 7,100', 8/29/80.

Salix eastwoodiae Heller, Eastwood's Willow.

Occasional, central and southern Seven Devils, 7,000-8,000'.

Bingham 329, ID and WS, Bingham and Miller 371, ID, and Bingham and Miller 380, ID and WS, northwest shores of Black Lake, 7,200', 7/17/81; outlet of Lower Cannon Lake, 7,000', 7/27/81; and outlet of Dog Lake, 8,000', 7/28/81; respectively.

Salix exigua Nutt. ssp. *exigua* var. *exigua*, Coyote Willow.

Scarce, lower Rapid River only, 2,600' ±.

Bingham and Miller Sight Record, Rapid River 1¼ mi above Blue Gulch, along trail 113, 2,600', 6/8/82.

Salix scouleriana Barratt, Scouler's Willow.

Common, entire Seven Devils and Rapid River, 5,000-7,700'.

Baker 11295, ID, summit of Kinney Point (7,125'), 9/3/53.

Bingham 280, ID, flat under open *Pinus ponderosa* forest at the end of the Low Saddle spur rd. in Low Saddle, 5,400', 8/8/81 (some individuals to 12" d.b.h.).

*Christ 12603, ?NY, on wooded slope in cirque below Seven Devils Lake, 7/13/41.

Lewis 2263a, BOIS, OGDF, Steele Stand 72-Pa-24, along the Bear-Cuprum rd. 002 at the Bear-Indian Cr. divide, sec. 21, T. 20 N., R. 3 W., 5,790', 6/12/72.

Plus 32 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle south to Huntley Gulch, 5,000-7,700'.

Heuchera cylindrica Dougl. var. *alpina* Wats., the more hairy, alpine variety of the Roundleaf Alumroot.
Uncommon, central, eastern, and southern Seven Devils, 7,200-8,100'.
Baker 12044, ID, open alpine slopes, Seven Devils Camp, 7/21/54.
*Christ 8689 & 12596, ?NY, on high ridges near Black Lake, 8/8/37; and cliffs in cirque below Seven Devils Lake, 7/13/41; respectively.
C. Johnson 9/1/83, BKR 2429, Plot 7070, west of the Old Boise Trail 101 at Fire Camp Saddle, *Festuca idahoensis-Danthonia intermedia* community, 7,180', 9/1/83.
Wellner 1679, ID, north of the lookout on Pollock Mt., 8,050', 8/6/78.
Plus 1 C. Johnson Sight Record, Plot 7007, northeast shore of Haas Lake, 7,240', 8/9/83.

Heuchera cylindrica Dougl. var. *cylindrica*, Roundleaf Alumroot.
Scarce, central Seven Devils, 8,400' ±.
Christ 12545, ID, on cliffs, Heavens Gate, 7/12/41.

Heuchera cylindrica Dougl. var. *glabella* (Torr. and Gray) Wheelock, the finely pubescent variety of the Roundleaf Alumroot.
Scarce, central Seven Devils, 7,700' ±.
C. Johnson Sight Record, Plot 7036, east of the Old Boise Trail 101 ca. 1/3 mi south of The Narrows, 7,660', 8/14/83.

Heuchera grossulariifolia Rydb. var. *grossulariifolia*, Gooseberry-leaved Alumroot.
Common, entire Seven Devils and Rapid River, 5,000-8,000'.
Bingham and Miller 405 & 477, ID, open southeast-facing crevices in bedrock outcropping, south side of the dry fork of Bridge Cr. below Seven Devils Lake, ca. ¼ mi south-southwest of Seven Devils Guard Station, 7,300', 7/26/81; and moist, north-facing, mossy base of talus slope along the lower Rapid River trail 113 ca. 1¼ mi above Blue Gulch, 2,650', 7/8/82; respectively.
*Christ 12479, ?NY, on crags and in crevices, Seven Devils Ridge, 7/11/41.
Q. Jones 222, ID and WS, in cracks in rocks, Heavens Gate, 7/13/50.
Plus 26 Sight Records by Bingham and Miller, Camp Howard Triangulation Station to Lockwood Saddle, 5,300-8,000'.

Heuchera micrantha Dougl. var. *micrantha*, Small-flowered Alumroot.
Scarce, Rapid River only, 2,500-3,400'.
Bingham and Miller 494, ID and WS, base of mossy, north-facing talus in the bottom of the Rapid River along trail 113 ca. 1¼ mi above Blue Gulch, 2,650', 7/8/82.
Bingham and Miller Sight Record, along trail 113 near the mouth of Cottonwood Cr. in the bottom of the west fork of the Rapid River, 3,400', 7/8/82.

Lithophragma parviflora (Hook.) Nutt., Small-flowered Prairie Star.
Frequent, entire Seven Devils and Rapid River, 5,000-6,800'.
Aldrich 7/04/07, ID 2371, Camp Howard (prob. the cow camp), 5,000', 7/04/07.
Plus 13 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, Big Canyon to Lockwood Saddle and lower and west forks Rapid River, 5,000-6,800'.

Mitella breweri Gray, Brewer's Mitrewort.
Scarce, central Seven Devils, 6,700' ±.
Bingham and Miller 162, ID and WS, streambank in a moderately dense *Abies lasiocarpa-Picea engelmannii* forest, bottom of Hanson Cr. ca. 0.1 mi east of the Old Boise Trail 101, 6,700', 7/17/80.

Mitella pentandra Hook., Alpine Mitrewort.
Frequent, entire Seven Devils, 5,600-7,300'.
Bingham 292A, ID, deep silty loam of muddy streambank, 1/3 shaded moderately dense forest of *Abies lasiocarpa*, *Pinus contorta*, and *Picea engelmannii*, along rd. 2060 on the banks of Meyer Cr., 5,800', 7/8/81.
*Christ 8362 & 12610, ?NY, springy place on mountainside, Black Lake, 8/8/37; and moist banks of Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41; respectively.

Packard 452, WS, wet, shaded streambank where the Brundage Trail crosses the west fork of Sheep Cr., 6,600' (nearer 6,800'), 7/28/38.

St. John and Mullen 8505, WS, wet, mossy log, Dry Diggins, 8,000', 7/21/27.

Plus 7 Sight Records by Bingham and Miller and C. Johnson.

Mitella stauropetala Piper, Side-flowered Mitrewort.

Common, entire Seven Devils and Rapid River, 5,000-7,100'.

Bingham and Miller 189, ID and WS, east-facing rocky slope in an open *Pseudotsuga menziesii* forest along the Old Boise Trail 101 ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80.

Q. Jones 231, ID, 4 mi toward Riggins from Heavens Gate (actually then from Windy Saddle along rd. 517), 7/14/50.

*Packard 327, ?WS, moist north slope in ponderosa pine stand, McGaffee Cow Camp, 5,500', 6/29/37.

St. John and Mullen 8386, WS, dense thickets, McGaffee Cow Camp, 5,400', 7/17/27.

Plus 20 Sight Records by Bingham and Miller, C. Johnson, and Steele, Big Canyon Saddle to Huntley Gulch, 5,000-7,100'.

Parnassia fimbriata Konig. var. *fimbriata*, Grass-of-Parnassis.

Frequent, central Seven Devils and upper west fork Rapid River, 6,700-7,900'.

Bingham and Miller 38, ID, and 235, ID and WS, open bog at the north end of the pond along the northeast side of Sheep Lake at the foot of the Goat Pass manway, 7,880', 7/22/79; and in a 1/3-shaded bog under an *Abies lasiocarpa* forest along the Ruth Lake trail ca. 0.1 mi east of the lake, 7,200', 8/27/80; respectively.

Brewer 30, Council R.D., Jackley Guard Station (apparently near and north of the lookout site), sec. 12, T. 21 N. (22 N.), R. 3 W. (2 W.), 7,000', 7/30/28.

Hibbs 8/17/37, WS 107994, in small spring near Hibbs Cow Camp, 7,900', 8/17/37.

LaZelle 3, ID, west edge of Seven Devils Lake, 7,500', 8/28/63.

Plus 14 Sight Records by Bingham and Miller, Windy Saddle to Deb's Corral and Ruth Lake, 6,700-7,800'.

Saxifraga arguta D. Don, Brook Saxifrage.

Common, entire Seven Devils and west fork Rapid River, 5,600-7,900'.

*Baker 12253, ?ID, moist woods along Shingle Cr. (prob. along rd. 517), 7/31/54.

Bingham and Miller 37, ID, and 157, ID and WS, open bog at the north end of the pond at the northeast end of Sheep Lake, at the foot of the Goat Pass manway, 7,880', 7/22/79; and in the bottom of Hanson Cr. under a dense *Abies lasiocarpa-Picea engelmannii* forest ca. 0.1 mi down the creek from the Old Boise Trail 101, 6,700', 7/17/80; respectively.

*Christ 8626 & 12688, ?NY, springy places on mountainside, Black Lake, 8/8/37; and creek banks at the crossing of Sheep Cr. trail (112), and the fork of Sheep Cr. (prob. the west fork), 7/17/41; respectively.

Packard 451, WS, wet, shaded streambank where the Brundage Trail crosses the west fork of Sheep Cr., 6,600', 7/28/38.

St. John and Mullen 8454, WS, creek bank, Dry Diggins, 7,300', 7/20/27.

Plus 23 Sight Records by Bingham and Miller, from along rd. 1819 just southwest of Caribou Cr. south to along rd. 106 2 mi north of Lockwood Saddle, 5,600-7,900'.

Saxifraga bronchialis L. var. *austromontana* (Wieg.) Jones, the narrow-leaved variety of the Matted Saxifrage.

Uncommon, central Seven Devils, 7,100-8,700'.

Bingham 10 & 102, ID, rock crevices at top of north-facing cliffs immediately north of Heavens Gate Lookout, 8,430', 7/21/79; and west-facing, bedrock ridgetop, crevices under boulders, ca. ¼ mi down the northwest ridge off He Devil Mt., 8,750', 7/26/79.

*Christ 12540, ?NY, ledges on peak, Heavens Gate, 7/12/41.

*Nelson and Nelson 3025, ?RM, top of He Devil, 8/10-15/38.
St. John and Mullen 8580, WS, rocky ledge on He Devil Mt., 9,000', 7/24/27.
Steele 937, BOIS, Heavens Gate, 8,400', 8/8/74.
Plus 1 Sight Record by Bingham and Miller, north-facing, moist bedrock crevices along trail 112 in the head of the east fork of Sheep Cr. ca. ½ mi west-northwest of Windy Saddle, 7,100', 8/10/81.

Saxifraga integrifolia Hook. var. *claytonaefolia* (Canby) Rosend., the white-petaled, deltoid-leaved variety of Swamp Saxifrage.
Scarce, northern and central Seven Devils, 5,000-7,800'.
Comstock 92, WS, north slope of Lightning Cr. 6 mi from the Snake River, ? elev., 5/12/39.
Tisdale Sight Record, vicinity of Bald Mt., 7,600-7,800', 7/16/79.

Saxifraga integrifolia Hook. var. *columbiana* (Piper) Hitchc., the yellow-petaled and glabrous-petioled variety of Swamp Saxifrage.
Scarce, central Seven Devils, 8,000-8,400'.
*Christ 12572, ?NY, grassy west slopes, Heavens Gate, 7/12/41.
Q. Jones 221, WS, vicinity of Heavens Gate Lookout, 7/13/50.

Saxifraga mertensiana Bong., Merten's Saxifrage.
Scarce, central Seven Devils, 7,200-7,800' +.
*Christ 12453, ?NY, moist cliffs above Seven Devils Lake.
Christ 12664, ID and WS, scattered in cliffs about Sheep Cr. Lake No. 4 (Sheep Lake), 7/16/41.

Saxifraga occidentalis Wats. var. *idahoensis* (Piper) Hitchc., the Idaho variety of Western Saxifrage.
Scarce, northern and central Seven Devils, 7,800-8,000'.
Packard 302 & 344, WS, moist soil near Sheep Cr. Lake No. 4 (Sheep Lake) at the foot of He Devil Mt., 8,800' (the lake actually lies at an elev. of 7,825'), 6/27/37; and moist, rocky soil on the divide between the forks of Sheep Cr. (prob. along trail 112 at about 8,000' elev.), 6/30/37; respectively.

Saxifraga occidentalis Wats. var. *occidentalis*, Western Saxifrage.
Scarce, central Seven Devils, 8,000' ±.
Bingham and Miller 360, ID and WS, west-facing, open, consolidated talus slope above the east shore of Mirror Lake, 8,000', 7/26/81.

Saxifraga occidentalis Wats. var. undet. or indeterminate, Western Saxifrage.
Bingham and Miller 290, ID, east-facing, ¼-shaded cliff crevices ca. 200' west of Crater Lake on the steep, wooded cirque wall east of the Old Boise Trail 101, 6,740', 7/9/81.
Plus 6 Bingham and Miller Sight Records, vicinities of Buckhorn Spring, Camp Howard Triangulation Station, ¼ mi below the main forks of the Rapid River, along the west fork of the Rapid River 1 mi below Bridge Cr., shores of Seven Devils Lake, and south of Cow Cr. Saddle, 5,300-6,000'.

Saxifraga rhomboidea Greene, Diamondleaf Saxifrage.
Scarce, central Seven Devils, 7,600' ±.
*Christ 12446, ?NY, moist cliffs above Seven Devils Lake, 7/11/41.

Suksdorfia ranunculifolia (Hook.) Engelm., Buttercup-leaved Suksdorfia.
Scarce, central Seven Devils, 7,200' ±.
*Christ 12583, ?NY, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Tiarella trifoliata L. var. *unifoliata* (Hook.) Kurtz, Foam Flower or False Mitrewort.
Uncommon, northern and central Seven Devils, 5,000-7,300'.
Bingham and Miller 590A, ID, east-facing, ½-shaded, cutover streambottom in a *Pseudotsuga menziesii, Pinus ponderosa, Abies grandis* stand in the northernmost fork of Shingle Cr. crossed by rd. 517 ca. ½ mi up the road from its 2d crossing of Papoose Cr. in sec. 26, 4,900', 8/17/82.
Bingham and Miller Sight Records: vicinities of Baldy Lake, 7,200'; east fork of Sheep Cr. 1½ mi north of trail 112, 5,800'; Old Town at the jct. of trails 113 and 191, 6,200';

Ruth Lake, 7,300'; along trail 101 ½ mi northeast of Horse Heaven Cr., 7,300'; and along trail 124 ca. ¼ mi northwest of the south fork of Little Granite Cr., 6,600'.

C. Johnson Sight Record, vicinity of rd. 2060 at Kirkwood Cr., 5,220'.

Scrophulariaceae

Besseya rubra (Dougl.) Rydb., Red Besseya.

Uncommon, lower northern Seven Devils, 5,000-5,600'.

Bingham 459, open basalt-rock ridgetop with grass-forb stand, immediately south of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82.

Plus 5 Sight Records by Bingham and Miller and C. Johnson, Big Canyon Saddle to Dixon Corrals, 5,000-5,600'.

Castilleja angustifolia (Nutt.) G. Don, Northwest Paintbrush.

Scarce (mostly below 5,000'), central Seven Devils, 5,000-6,800'.

*Packard 448, ?WS, talus slopes near the "Brundage Trail," just west of the west fork of Sheep Cr., 6,800', 7/28/38.

Castilleja applegatei Fern. var. *fragilis* (Zeile) N. Holmgren, the tall variety of Wavy-leaved Paintbrush.

Frequent, central and southern Seven Devils, 6,800-7,800'.

Bingham and Miller 611, ID and WS, in a grass/forb stand on an open, rocky ridgetop at the end of rd. 106 at the Sheep Rock nature trail sign, 6,800', 7/27/83.

Brewer 23, IDF, Iron Springs Camp, sec. 13, T. 22 N., 7,000' (at the spring ca. 0.2 mi north of Holbrook Saddle, the spring actually is about 8,000'), 7/21/28.

*Christ 8692, ?NY, on rocky ridges near Black Lake, 8/8/37.

Christ 12558, ID, grassy ridges, Heavens Gate, 7/12/41.

C. Johnson 8/10/83, BKR 2490, Plot 7015, above trail 124 ca. 0.1 mi west of the summit of Potato Hill, *Artemisia tridentata/Festuca idahoensis* community, 7,730', 8/10/83.

*Kruckeberg 3187, ?WTU, north-facing, wooded slopes at the end of the road from Riggins (rd. 517 prob. at Windy Saddle), 7/30/52.

*Ownbey and Meyer 2093, ?WS (as var. *viscida* (Rydb.) Ownbey), rocky slope, Hibbs Cow Camp, 6/26/40.

*Packard 334, ?WS (as var. *viscida* (Rydb.) Ownbey), dry, barren soil at the foot of He Devil Mt., 8,900' (prob. not over 8,400'), 6/29/37.

?*Pennell 20804, ?PH, ?NY, open, rocky iryolytic slope, Smith Mt., 7,400-7,700', 7/9/37 (called *C. undulata* by Pennell but identified by N. Holmgren (NY) as *C. applegatei* Fern. var. *pinetorum* (Fern.) N. Holmgren, which Hitchcock, Cronquist and Ownbey (1959) consider to be var. *applegatei*. (But, Hitchcock and others (loc. cit.) declare Idaho specimens to be var. *fragilis*).

Plus 4 Sight Records by C. Johnson.

Castilleja covilleana Hend., Rocky Mountain Paintbrush.

Scarce, eastern central Seven Devils, 8,000' ±.

Wellner 1686, ID, north of the lookout on Pollock Mt., 8,050', 8/6/78 (somewhat northwest of the species' main distribution).

Castilleja cusickii Greenm., Cusick's Paintbrush.

Frequent, northern and occas. central Seven Devils, 5,100-7,600'.

Baker 12031, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham 462, ID, grass/forb stand on open, rocky (basalt) ridgetop at Cow Cr. Saddle, 5,250', 5/25/82.

C. Johnson 7/1/83, BKR 2539, Plot 999, 75' northwest of rd. 1819 southwest of Cold Springs Cow Camp, 6,700', 7/1/83.

Tisdale 7/13/78, IDF 78352, and 7/11/79, IDF 81139, 2 mi west of Cold Springs Lookout, 6,800', 7/13/78; and 1½ mi west of Cold Springs Lookout, 6,600', 7/11/79; respectively.

Plus 6 Sight Records by Bingham and Miller and C. Johnson, Dixon Corrals to Cold Springs Lookout site, 5,100-6,900'.

Castilleja glandulifera Pennell, Glandular Indian Paintbrush.

Scarce, northern Seven Devils, 5,000' ±.

Bingham and Miller 510, ID and WS, *Festuca idahoensis/ Agropyron spicatum* stand on southeast-facing slope just north of Big Canyon Saddle, 5,050', 6/11/82.

Castilleja hispida Benth. var. *acuta* (Pennell) Ownbey, the variety of the Harsh Paintbrush having sharply tipped calyx lobes.

Common, entire Seven Devils, 5,000-8,000'.

*Aldrich 7/4/07, ?ID , Camp Howard, 5,000', 7/4/07.

Bingham and Miller 121 & Bingham 461, ID and WS, open forest on southeast-facing, rocky-gravelly slope on the Cannon-Hanson Cr. ridge 1/3 mi north-northeast of the jct. of Hanson Cr. and the Old Boise Trail, 7,400', 7/15/80; and open sagebrush-forb stand on basalt rock ridgetop immediately south of rd. 420 at Cow Cr. Saddle, 5,250', 5/25/82; respectively.

Q. Jones 219, ID, vicinity of Heavens Gate, 7/13/50.

Packard 281 & 286, WS, timbered bench north of Little Granite Cr., 5,000', 6/22/37; and above the head of the north fork of Little Granite Cr., 7,400', 6/26/37; respectively.

*Pennell 20796, ?PH, open coniferous forest of Smith Mt., 5,200-5,400', 7/9/37.

Plus 32 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

?*Castilleja linariaefolia* Benth., Narrow-leaved Paintbrush.

Brewer 19, Council R.D., Iron Springs Camp, sec. 13, T. 22 N., R. 2 W., 7,000', 7/23/28 (but well to the north of the species' usual southern Montana, southern Idaho, and southeastern Oregon distribution).

Castilleja miniata Dougl. var. *miniata*, Scarlet Paintbrush.

Frequent, entire Seven Devils, 5,000-8,400'.

Baker 11316 & 12019, ID, grassy, open meadow, Kinney Point, 9/3/53; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 584, ID, steep, north-facing roadcut in Douglas-fir/ninebark h.t., ca. ¼ mi up rd. 517 from its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Christ 12524, ID, open, grassy east slopes, Heavens Gate, 7/12/41.

Davis 2357, WS, dry hillside, Heavens Gate, 6/28/40.

*Pennell 20799 & 20799a, ?PH, both collections open coniferous forest, south slope of Smith Mt., 5,600-5,900', 7/9/37 (20799 with red bracts and 20799a with carmine bracts).

Plus 11 Sight Records by C. Johnson, Cold Springs Lookout site to Smith Mt., 5,000-8,400'.

Castilleja oresbia Greenm., Pale Wallowa Paintbrush.

Scarce, southern Seven Devils, 5,200' ±.

Steele 1427, BOIS, upper Fawn Cr., sec. 4, T. 19 N., R. 2 W., 5,200', 7/8/80.

?*Castilleja parviflora* Bong. var. undet., common name unknown.

Baird 6/27/72, Council R.D., 2 mi below Placer Basin, 5,000', 6/27/72 (but all 5 vars. are Cascade and Olympic Mt. plants).

Castilleja rhexifolia Rydb., Rhexia-leaved Paintbrush.

Common, entire Seven Devils, 6,400-8,400'.

Baker 12091, ID, steep banks below Heavens Gate, 7/21/41.

Bingham and Miller 21 & 73, ID, and 170, ID and WS, edge of small subalpine meadow in moderately open *Abies lasiocarpa-Pinus albicaulis* forest ca. 0.1 mi southwest of Heavens Gate Lookout just west of the Snake-Salmon Rivers divide, 8,300', 7/21/79; west-facing meadow in the valley ca. 2/5 mi directly north of He Devil Mt. and 2/5 mi east-southeast of Rock Island Lake, 8,250', 7/25/79; and rocky, east-facing slope in moderately dense *Abies lasiocarpa-Pinus contorta* forest along the Old Boise Trail 101 ca. ¼ mi south of the Cannon Lake trail, 6,700', 7/18/80; respectively.

*Christ 12546 & 12655, ?NY, north face of peak, Heavens Gate, 7/12/41; and marshy shore of Sheep Cr. Lake No. 3 (Gem Lake), 7/16/41; respectively.

Davis ? , IDF 83078, moist hillside, Smith Mt. Lookout, 7/3/40.

Ownbey and Meyer 2092, WS, open *Abies* woods, Hibbs Cow Camp, 6/26/40.

Packard 437, WS, moist, shady spot in woods near "The Swamps," Dry Diggins, 7/28/38.

Pennell 20817, WS, grassy, coniferous forest below Black Lake, 7,000-7,800', 7/9/37.

Plus 25 Sight Records by Bingham and Miller, Cold Springs Lookout site to Lockwood Saddle, 6,400-8,100'.

Chionophila tweedyi (Canby and Rose) Hend., Chionophila.

Common, central and southern Seven Devils, 7,300-8,400'.

*Baker 12035, ?ID, ? open alpine slopes, Seven Devils Camp, 7/21/54 (Baker's field notes are unclear as to the locality of this collection, but the preceding and the following collections are from this locality).

Bingham and Miller 20, ID, mountain heather/sedge meadow in a moderately open subalpine forest of *Pinus albicaulis* and *Abies lasiocarpa*, ca. 0.1 mi southwest of Heavens Gate Lookout, 8,300', 7/21/79.

Brewer 28, Council R.D., Black Lake, sec. 3, T. 21 N., R. 3 W., 7,500', 7/21/28.

Christ 12475, WS, and 12550, ID, Seven Devils Ridge, 7/11/41; and in colonies on crest of divide, Heavens Gate, 7/12/41; respectively.

*Christ 12647, ?NY, soil pockets on ridges between Sheep Cr. Lakes No. 3 and 4 (Gem and Sheep Lakes), 7/16/41.

Kruckeberg 3184, WS, WTU, clearings and swales on north-facing wooded slope at end of Seven Devils rd. (rd. 517 prob. at Windy Saddle), 7,500', 7/30/52.

Nelson and Nelson 2993, WS, Horse Heaven, 8/10-15/38.

Ownbey and Meyer 2095, WS, Heavens Gate, 6/27/40.

Packard 308 & 467 (latter mislabeled 667), WS, He Devil Mt., 9,000' (prob. nearer 8,400'), 6/27/37; and along the "Brundage Trail" between the forks of Sheep Cr., 8,000', 8/28/38.

St. John and Mullen 8443, WS, summit of Dry Diggins, 8,000', 7/20/27.

Plus 9 Sight Records by Bingham and Miller.

Collinsia parviflora Lindl., Small-flowered Blue-eyed Mary.

Common, entire Seven Devils, 5,000-8,100'.

Aldrich 7/4/07, ID 4853, Camp Howard (prob. the cow camp), about 5,000', 7/4/07.

Bingham and Miller 150, ID and WS, in meadow along the Old Boise Trail ca. 0.1 mi northeast of Hanson Cr., 6,800', 7/17/80.

*Christ 12529, ?NY, thin soils on open east slopes, Heavens Gate, 7/12/41.

*Pennell 20800, ?PH, open coniferous forest, south slope of Smith Mt., 5,600-5,800', 7/9/37.

Plus 24 Sight Records by Bingham and Miller, C. Johnson, Steele, and Tisdale, Big Canyon Saddle to Huntley Gulch, 5,000-8,100'.

Cordylanthus capitatus Nutt., Clustered Birdbeak.

Occasional, central and southern Seven Devils, 5,000-7,000'.

Bingham and Miller 431, ID, open, rocky, east-facing slope with forbs, ca. 1/3 mi north of the dropoff along Dry Diggins Ridge trail 140 at 2¼ mi north of the jct. of trails 112, 57, and 140 at the Iron Phone, 7,040', 8/12/81.

Davis 2495, WS, 1 mi northwest of Bear (prob. along rd. 002), ? elev., 7/2/40.

St. John and Mullen 8467, WS, gravel ridge, Dry Diggins, 7,000', 7/20/27.

Linaria dalmatica (L.) Mill., Dalmatian Toadflax (Eastern Mediterranean Region introduction).

Scarce, lower southern Seven Devils, 5,000' ±.

Baird 9/8/71, Council R.D., side of rd. 105, 1 mi above Cuprum, 5,000', 9/8/71.

Mimulus breweri (Greene) Cov., Brewer's Monkey Flower.

Scarce, central Seven Devils, 7,600-8,000'.

Christ 12607, ID, dry cliffs near Seven Devils Lake, 7/13/41.

Ownbey and Meyer 2076, WS, dry, rocky soil in opening in *Pinus-Picea-Abies* forest, headwaters of Sheep Cr., 6/26/40.

Mimulus guttatus DC. var. *guttatus*, Yellow Monkey Flower.

Frequent, entire Seven Devils and Rapid River, 5,000-8,000'.

Baker 12065, ID, wet marshy ground about spring, Seven Devils Guard Station, 7/21/54.

Bingham and Miller 570, ID and WS, at the uppermost (2d crossing) of rd. 517 over the south fork of Papoose Cr., roadside creek bottom bordered by open *Abies lasiocarpa-Picea engelmannii-Pinus contorta* forest, 6,400', 8/17/82.

Brewer 117, Council R.D., Jackley Guard Station (apparently near the lookout), sec. 13, T. 22 N., R. 3 W. (actually 2 W.), 7,000', 8/17/30.

*Christ 8642 & 8699, ?NY, along rills leading into Black Lake, 8/8/37; and at edges of pool in tundra near Pyramid Peak, 8/8/37; respectively.

Plus 7 Sight Records by Bingham and Miller, Caribou Cr. to Rankin Mill and lower Rapid River, 5,900-8,000'.

Mimulus lewisii Pursh, Lewis Monkey Flower.

Frequent, central and southern Seven Devils, 7,200-8,000'.

Baker 11323 & 12061, moist soil, edge of spring, 6 mi north of Cuprum (prob. along rd. 106), 9/3/53; and wet, marshy ground about spring, Seven Devils Guard Station, 7/21/54; respectively.

Bingham and Miller 199, ID and WS, small, open, sedge-forb creek bottom immediately below the watering trough at the bottom of the Horse Heaven Lookout pasture ca. 1/3 mi south of the lookout cabin along trail 192, Adams Co., 7,900', 8/24/80.

Brewer 22, Council R.D., Iron Springs, sec. 13, T. 22 N., R. 2 W. (presumably a Forest Service camp at the spring ca. 0.2 mi north of Holbrook Saddle, and not at the Old Iron Springs mining town in Paradise Cr.), 7,000', 7/21/28.

*Christ 8622, ?NY, springy places on mountainside, Black Lake, 8/8/37.

Hibbs 8/20/37, WS 107728, in small spring near Hibbs Cow Camp, Dry Diggins, 8/20/37.

*Nelson and Nelson 2977, ?RM, Dry Diggins Camp, 8/10-15/38.

St. John and Mullen 8483, WS, along streambank, Dry Diggins, 7,300', 7/20/27.

Plus 6 Sight Records by Bingham and Miller.

Mimulus moschatus Dougl. var. *moschatus*, Musk-flower.

Scarce, central and southern Seven Devils, 5,200-9,000'.

*Pennell 20797, ?PH, along cold stream and springhead, Smith Mt., 5,200-5,400' (but from the elev., well south toward the jct. of the Black Lake rd. 112 with rd. 105), 7/9/37.

St. John and Mullen 8539, WS, moist rock chimney on He Devil Mt., 9,000', 7/24/27.

Mimulus nanus Hook and Arnott, Dwarf Purple Monkey Flower.

Occasional, northern and central Seven Devils, 5,200-7,800'.

Bingham and Miller 411, ID, west-facing, rocky slope in an *Abies lasiocarpa-Pinus albicaulis* forest, along trail 112 ca. ¼ mi westward from its summit between the forks of Sheep Cr., 7,800', 8/10/81.

Packard 463, WS, west slope of the ridge between the forks of Sheep Cr., 7/28/38.

Plus 1 Sight Record by Tisdale, vicinity of Low Saddle, 5,200', 7/13/78.

Mimulus tilingii Regel var. *tilingii*, Mountain Monkey Flower.

Scarce, central and southern Seven Devils, 7,200-7,800' ±.

Bingham 318, ID, on gravelly silt trapped by an old streamside stump, by the small stream passing through the south end of the campsite along the northwest side of Black Lake, open, 7,200', 7/17/81.

Christ 12707, ID, sliderock on west slopes, Sheep Cr. Trail, 7/17/41.

Orthocarpus tenuifolius (Pursh) Benth., Thin-leaved Owl-clover.

Uncommon, northern and central Seven Devils, 5,000-6,900'.

Bingham 302, ID, open, northeast-facing weedy forb-grass stand ca. ¼ mi north along the main ridge from Sawpit Saddle, 5,050', 7/8/81.

Davis 2258, WS, dry, open hillside, Grave Point Lookout, 6/24/40.

Plus 5 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, including sightings at Cold Springs Lookout, Cow Cr. Saddle, Cold Springs Cow Camp, and near the Old Timer Mine along trail 110, 5,250-6,900'.

Pedicularis bracteosa Benth. var. *siifolia* (Rydb.) Cronq., the cream-coraled, glabrous-flowered variety of Bracted Lousewort.

Frequent, entire Seven Devils, 5,000-7,600'.

Bingham and Miller 135, ID and WS, open, northeast-facing sedge meadow in an open *Picea engelmannii, Abies lasiocarpa, Pinus albicaulis* stand, on the south side of the bottom of Dog Cr. ca. ½ mi below the lake, 7,600', 7/16/80.

Christ 12625, ID, along the trail (prob. 124) from Hibbs Cow Camp to Baldy Lake, 7/15/41.

Packard 438, WS, shaded woods near "The Swamps," Dry Diggins, 7/28/38.

*Pennell 20818, ?PH, grassy, coniferous forest below Black Lake, 7,000-7,800' (lake elev. is 7,200'), 7/9/37.

Plus 15 Sight Records by Bingham and Miller, Big Canyon Saddle to Towsley Spring, 5,000-7,600'.

Pedicularis bracteosa Benth. var. undet., Bracted Lousewort.

*Christ 12726, ?NY, timberland surrounding Sheep Cr. Swamp, 7/17/41.

C. Johnson Sight Record, Plot 7073, west of the Old Boise Trail 101 ca. 1 mi south of rd. 1819 at the trailhead southeast of Cold Springs Lookout, 6,600', 9/1/83.

Pedicularis contorta Benth. var. *contorta*, Coiled-beak Lousewort.

Common, entire Seven Devils, 6,200-8,200'.

Baker 11310 & 12016, ID, moist, shaded slope, Sheep Rock, 9/3/53; and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 21, ID, west-facing, edges of *Luzula hitchcockii* meadow in *Abies lasiocarpa, Pinus albicaulis* open stand ca. 0.1 mi south-southwest of Heavens Gate Lookout, 8,300', 7/21/79.

*Christ 8675 & 12501, ?NY, talus slopes near Black Lake, 8/8/37; and under cover in conifer grove, Seven Devils Camp, 7/12/41; respectively.

Davis 2392, WS, dry hill under pine, Heavens Gate, 6/28/40.

C. Johnson 8/12/83, BKR 2567, Plot 7025, above trail 56 and ca. ¼ mi south-southwest of Three Cr. Point, *Pinus albicaulis-Abies lasiocarpa/Vaccinium scoparium* community, 7,900', 8/12/83.

Q. Jones 220, ID and WS, edges of mountain meadow, Heavens Gate, 6/13/50.

Packard 342, WS, moist streambank near the head of the north fork of Little Granite Cr., vicinity of Hibbs Cow Camp, Dry Diggins, 6/29/37.

*Pennell 20803 & 20807, ?PH, open, coniferous forest, south slope of Smith Mt., 7,200-7,700', 7/9/37; and clefts in ryolitic rock, Smith Mt., 7,500-7,700', 7/9/37; respectively.

St. John and Mullen 8471, WS, grassy ridge, Dry Diggins, 7/20/27.

Plus 27 Sight Records by Bingham and Miller, C. Johnson, and Tisdale, including vicinity of Cold Springs Lookout.

Pedicularis groenlandica Retz., Elephant's Head.

Scarce, central Seven Devils, 7,000' ±.

C. Johnson Sight Record, Plot 7021, east of trail 124 ca. 1 mi south of Hibbs Cow Camp, 7,050', 8/11/83.

Pedicularis racemosa Dougl. var. *alba* (Pennell) Cronq., the white-flowered variety of the Leafy Lousewort.

Common, entire Seven Devils and Rapid River, 5,300-7,700'.

Baker 12097, ID, shady woods 11 mi west of Riggins (along rd. 517 on McClinery Ridge), 7/21/54.

*Christ 8648 & 12683, ?NY, under cover in *Abies lasiocarpa* groves, Black Lake, 8/8/37; and with Douglas-fir along the Sheep Cr. trail, 7/17/41; respectively.

Hibbs 8/17/37, WS 107146, rocky, shallow soil near "The Swamps," on the trail to the 1st Sheep Cr. Lake (prob. trail 123 and Basin Lake), 8/17/37.

LaZelle 15, ID, in shade at the west end of Seven Devils Lake, 7,500', 8/28/63.

*Nelson and Nelson 3017, ?RM, Rapid River trail, 8/10-15/38.

*Pennell 20813, ?PH, Black Lake, 7,200-7,700', 7/9/37.

Plus 21 Sight Records by Bingham and Miller, C. Johnson, and Steele, including vicinity of Cold Springs Lookout.

Penstemon attenuatus Dougl. var. *attenuatus*, Taper-leaf Penstemon.

Occasional, central and southern Seven Devils, 6,800-7,800'.

*Christ 12515, ?NY, open, grassy mountainside 1 mi east of Seven Devils Camp, 7/12/41.

*Pennell 20801 & 20806, ?PH, open, coniferous forest, south slope of Smith Mt., 6,800-7,000', 7/9/37; and clefts of ryolitic rock, Smith Mt., 7,500-7,700', 7/9/37; respectively.

Penstemon attenuatus Dougl. var. *militaris* (Greene) Cronq., the large-flowered variety of the Taper-leaf Penstemon.

Uncommon, entire Seven Devils, 5,100-7,600'.

Bingham and Miller 447, ID, on rocky loam in open, south-southeast-facing boulderfield at edge of open *Abies lasiocarpa, Picea engelmannii, Pinus albicaulis* forest along the Horse Heaven Lake manway ca. 1/8 mi below the lake, 7,500', 8/18/81.

*Christ 8673 & 8702, ?NY, rocky prominence, Black Lake, 8/8/37; and exposed rocky ridges near Black Lake, 8/8/37; respectively.

C. Johnson 8/30/83, BKR 2591, Plot 7064, a fire succession community east of trail 217 in Horse Pasture Basin, ca. ¼ mi southeast of Joes Gap, 7,620', 8/30/83.

C. Johnson Sight Record, Plot 781, table lands ca. ¼ mi south-southeast of Dixon Corrals, 5,150', 6/25/82.

Penstemon attenuatus Dougl. var. *palustris* (Pennell) Cronq., the small-flowered variety of the Taper-leaf Penstemon.

Scarce, central Seven Devils, 7,400' ±.

C. Johnson Sight Record, Plot 7009, above the Old Boise Trail 101 ca. ¼ mi southeast of Haas Lake, 7,350', 8/9/83.

Penstemon deustus Dougl. var. *deustus*, Hot-rock, White-flowered Penstemon.

Uncommon, central and southern Seven Devils and Rapid River, 5,000-7,000'.

Bingham and Miller 486, ID and WS, in metamorphic rock crevices on a south-facing slope in the *Agropyron spicatum/Celtis reticulata* h.t., ca. 1.1 mi up the lower Rapid River trail 113 from the trailhead gate at the southwest end of the Circle C State Fish Hatchery, 2,350', 6/8/82.

Packard 283, WS, Willow Hill, between the forks of Little Granite Cr., 6/24/37.

*Pennell 20794, ?PH, open coniferous forest of Smith Mt., 5,100-5,200', 7/9/37.

Plus 3 Sight Records by Bingham and Miller, along trail 112 above the west fork of Sheep Cr. and McCrea Place and main forks of Rapid River, 2,700-7,000'.

***Penstemon elegantulus* Pennell, Lovely Penstemon.

Rare, northern Seven Devils, 5,100-5,550' (recommended for Federal Threatened status by Steele and others, 1981).

C. Johnson 6/25/82 & 6/29/82, BKR 2327 and ID 77384, Plot 791, on the table lands ca. ¼ mi south-southeast of Dixon Corrals, *Festuca idahoensis-Koeleria cristata* community, 5,105', 6/25/82; and Plot 793, ca. 200' southwest of Grave Point, 6/29/82.

Penstemon fruticosus (Pursh) Greene var. *serratus* (Keck) Cronq., the serrate-leafed variety of the Shrubby Penstemon.

Common, entire Seven Devils and west fork Rapid River, 6,200-8,400'.

Baker 12003 & 12080, ID, open alpine slopes, Seven Devils Camp, 7/21/54; and rock cliffs on a point above Seven Devils Guard Station, 7/21/54; respectively.

Bingham and Miller 56, ID, crevices in southeast-facing bedrock cliffs, open, just on the Mirror Lake side of the Bridge-Sheep Crs. divide at Goat Pass, 8,400', 7/24/79.

*Christ 8685 & 12522, ?NY, rocky spurs of higher ridges, Black Lake, 8/8/37; and rock outcrops on east slopes, Heavens Gate, 7/12/41; respectively.

Christ 12474, WS, Seven Devils Ridge, 7/11/41.

Henderson 3855, ID, Little Granite-Three Crs. divide ca. ¼ mi west of Hibbs Cow Camp, 6/6/77.

Nelson and Nelson 2964, RM, WS, Dry Diggins Camp, 8/10-15/38.

Ownbey and Meyer 2068, WS, headwaters of Sheep Cr., 6/26/40.

Packard 300, WS, cleft in basalt boulders near where the Brundage Trail crosses near the 1st Sheep Cr. Lake (Basin Lake), 8,300', 6/26/37.

*Pennell 20805, ?PH, clefts of ryolitic rock, Smith Mt., 7,500-7,700', 7/9/37.

Pennell 20819, PH, grassy, coniferous forest below Black Lake, 7,000-7,300', 7/9/37.

Plus 24 Sight Records by Bingham and Miller, including Crater Lake and the upper west fork of the Rapid River.

Penstemon gairdneri Hook. var. *oreganus* Gray, the opposite-leaved variety of Gairdner's Penstemon.

Scarce, southern Seven Devils, 5,000' ±.

*Christ 11061, ?NY, on basaltic scablands near Cuprum, 5/30/40.

Lewis 2268, BOIS, OGDF, near Steele Stand 72-Pa-24, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, sec. 21, T. 20 N., R. 3 W., 5,790', 6/12/82.

Steele 897, BOIS, Cuprum-Fruitvale rd. 127, sec. 11, T. 19 N., R. 2 W., 5,750', 6/27/74.

Penstemon glandulosus Dougl. var. *glandulosus*, Glandular Penstemon.

Occasional, entire Seven Devils, 6,600-8,200'.

C. Johnson Sight Records: Plot 7064, east of trail 217 at the west end of Horse Pasture Basin ca. ¼ mi southeast of Joes Gap, 7,620', 8/30/83; Plot 7073, west of the Old Boise Trail in the aspen grove ca. 1 mi south of the trail 101 trailhead southeast of Cold Springs Lookout, 6,600', 9/1/83; and Plot 7075, south of the lookout trail ca. 0.1 mi southwest of Heavens Gate Lookout, 8,170', 9/2/83.

Penstemon globosus (Piper) Pennell and Keck, Globe Penstemon.

Abundant, entire Seven Devils and west fork Rapid River, 5,000-8,000'.

Baker 12009, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 111 & 152, ID and WS, in open forest on a rocky, south-facing slope just northeast of Windy Saddle, 7,600', 7/14/80; and on gentle, southeast-facing slope in forest opening in *Pinus contorta*, *Abies lasiocarpa* forest, along the Old Boise Trail 101 just northeast of Hanson Cr., 6,800', 7/17/80; respectively.

*Christ 8649, 12496, & 12697, ?NY, grassy slope on Pyramid Peak, 8/8/37; very abundant on open, grassy slopes, Seven Devils Camp, 7/12/41; and open mountainside in sliderock along Sheep Cr. trail, 7/17/41; respectively.

Davis 2390, IDF and WS, Heavens Gate, 6/28/40.

*Hermann 12033 & 12050, ?NA, ?US, vicinity of Cold Springs Lookout, 6,900', 8/6/55; and vicinity of Heavens Gate Lookout, 8,400', 8/6/55; respectively.

Holmgren and Tillett 9597, WS, sagebrush slope, Kinney Point, 7/14/53.

Q. Jones 210, WS, vicinity of Heavens Gate Lookout, 7/12/50.

Kruckeberg 3188, WS, WTU, open, meadowy hillside above the Seven Devils Forest Station (Guard Station), 2 mi below Windy Saddle, 7,000', 7/30/52.

*Nelson and Nelson 2992, ?RM, Horse Heaven, 8/10-15/38.

Ownbey and Meyer 2099, WS, open meadows, Heavens Gate, 6/27/40.

Packard 313, WS, near Hibbs Cow Camp, 7,500-8,000', 6/28/37.

*Pennell 20795, ?PH, open, coniferous forest on Smith Mt. (south of the mountain along rd. 112), 5,200-5,400', 7/9/37.

St. John and Mullen 8489, WS, gravel ridge, Dry Diggins, 7,000', 7/20/27.

Tisdale 7/14/78, IDF 78357, vicinity of Cold Springs Cow Camp, 6,400', 7/14/78.

Plus 45 Sight Records by Bingham and Miller, C. Johnson, and Tisdale.

Penstemon montanus Greene var. *idahoensis* (Keck) Cronq., the entire-leaved variety of Mountain Penstemon.

Scarce, central Seven Devils, 7,500-8,200' ±.

*Kruckeberg 3193, ?WTU, on talus and in crevices above Sheep Cr. Lake No. 2 (Shelf Lake), 7,500', 7/31/52.

*Nelson and Nelson 2989, ?RM, Horse Heaven, 8/10-15/38.

Penstemon payettensis Nels. and Macbr., Payette Penstemon.

Occasional, central and southern Seven Devils, 7,200-7,700'.

Baird 6/27/72, Council R.D., 2 mi below Placer Basin Mine, 5,000', 6/27/72.

Bingham and Miller 614, ID and WS, open, south-facing rocky hillside with an open sagebrush-grass-forb stand, ca. ½ mi northwestward along trail 217 from its Black Lake rd. 112 trailhead north of High Dive, 7,200', 7/28/83.

*Nelson and Nelson 2698, ?RM, Dry Diggins Camp, 8/10-15/38.

Ownbey and Meyer 2082, WS, head of Little Granite Cr. near Hibbs Cow Camp, 6/26/40.

*Pennell 20810, ?PH, granitic soil, steep slopes, Smith Mt., 7,500-7,700', 7/9/37.

Penstemon rydbergii A. Nels., Rydberg's Penstemon.

Uncommon, central and southern Seven Devils, 6,800-7,300'.

Brewer 9, Council R.D., Granite Cr. (? the Granite Fk. of the Lake Fork of the Rapid River), White Cabin, sec. 11, T. 22 (?21) N., R. 2 W., 5,000', 6/26/28.

*Nelson and Nelson 2979, ?RM, Dry Diggins Camp, 8/10-15/38.

*Pennell 20802 & 20811, ?PH, open, coniferous forest, south slope of Smith Mt., 6,800-7,000', 7/9/37; and moist slopes, Black Lake, 7,200-7,700', 7/9/37; respectively.

Plus 2 Sight Records by C. Johnson, above the Old Boise Trail just south of Dog Cr., and northeast shore of Haas Lake, 6,950-7,240'.

Penstemon triphyllus Dougl., Whorled Penstemon.

Occasional, southern Seven Devils and Rapid River, 5,100' ±.

Bingham and Miller Sight Records: along the lower Rapid River trail 113 ca. 1/2 mi above the trailhead gate at the southwest end of the Circle C State Fish Hatchery, 2,400', 6/8/82; and along the west fork Rapid River trail 113 ca. 0.1 mi above the main forks in sec. 26, 2,700', 6/9/82.

Steele Sight Records, Stand 72-Pa-26, along the Bear-Cuprum rd. 002 at the Bear-Indian Crs. divide, 5,100', 6/12/72.

Penstemon venustus Dougl., Blue Mountain Penstemon.

Common, entire Seven Devils, 5,000-8,400' (so beautiful it is hard not to collect it more than once, see below).

Baker 11987 & 12041, ID, along Papoose Cr. 4 mi west of Riggins (along rd. 517, ? elev., 7/21/54) and open alpine slopes, Seven Devils Camp, 7/21/54; respectively.

Bingham and Miller 68, ID, and 203, 256, & 548, ID and WS, crevices in an open basalt outcropping immediately behind Seven Devils Guard Station, 7,200', 7/24/79; moderately dry, open, rocky, south-facing slope with a grass-sedge-forb stand, along the Old Boise Trail ca. ¼ mi east of Horse Heaven Saddle, 7,200', 8/24/80; crevices in loose rock and bedrock slope on a southwest-facing slope with a forb-sedge stand, along trail 124 between the north fork of Devils Farm Cr. and Potato Hill ca. 1½ mi north of Horse Heaven Saddle, 7,600', 8/28/80; and rocky ridgetop with an open grass-forb-sedge stand, ca. 150', northeast of Grave Point Lookout, 5,630', 7/21/82; respectively.

*Christ 8616, ?NY, rocky mountainside, Smith Mt. rd., 8/8/37.

Christ 12632, ID, rockslides on trail to Baldy Lake (either trail 124 or the Baldy Lake trail), 7/15/41.

Davis 2231, IDF, and 2538, WS, dry, rocky ridge, Grave Point Lookout, 6/24/40; and moist open woods, Black Lake, 7/3/40; respectively.

LaZelle 10, ID, roadside ¼ mi east of Seven Devils Camp, 8/29/63.

*Nelson and Nelson 2970, ?RM, and 2980 & 2981, ?RM and WS, Dry Diggins Camp; Dry Diggins Ranger Station; and Dry Diggins Ranger Station; respectively; all 8/10-15/38.

Packard 348, 449, & 470, WS, hillside above Silvers Ranger Station (now Adm. Site, in Shingle Cr.), ? elev., 6/30/37; talus slopes near the Brundage Trail just west of where it crosses the head of Sheep Cr. (prob. the west fork), 6,800', 7/28/38; and rocky slope beside the trail (prob. 101), McClinery Ridge below Heavens Gate Lookout, ? elev., 7/25/38; respectively.

*Pennell 20792, ?PH, basaltic soil below Frenchy (? Mailbox) Saddle, 5,100-5,200', 7/9/37.

St. John and Mullen 8440 & 8592, WS, head of Bernard Cr. (near McGaffee Cow Camp), 5,600', 7/19/27; and dry ledges on Dry Diggins, 7,500', 7/25/27; respectively.

Tisdale 7/13/78, IDF 83080, vicinity of Low Saddle, 5,200', 7/13/78.

Wellner 1701, ID, hillside northwest of Baldy Lake, 7,300', 8/22/78.

Plus 14 Sight Records by Bingham and Miller and C. Johnson.

Penstemon wilcoxii Rydb., Wilcox' Penstemon.

Common, entire Seven Devils and Rapid River, 5,000-7,600'.

Baker 12002, ID, moist, grassy bank, wooded slope 9 mi west of Riggins (prob. along rd. 517 on McClinery Ridge), 7/21/54.

Bingham and Miller 194, ID, and 376 & 495, ID and WS, east-facing, rocky slope in an open *Pseudotsuga menziesii* forest, along the Old Boise Trail 101 ca. 1/2-3/4 mi north of Hanson Cr., 6,800', 7/18/80; southeast-facing, rocky slope with an open *Pseudotsuga menziesii* forest, along the Old Boise Trail 101 ca. ¼ mi northeast of the Seven Devils Lake fork of Bridge Cr., 6,700', 7/27/81; and north-facing, half-open, moderately moist, rocky slope in a riparian forest with *Pseudotsuga, Abies grandis, Acer glabrum*, and *Betula occidentalis*, along the lower Rapid River trail 113 ca. 1½ mi above the mouth of Blue Gulch, 2,680', 6/8/82; respectively.

*Christ 12526, ?NY, rock outcrops on east slopes, Heavens Gate, 7/12/41.

*Nelson and Nelson 2980a, RM, Dry Diggins Ranger Station, 8/10-15/38.

Packard 461, WS, rocky, moist west slope of ridge between the forks of Sheep Cr., 7,500', 7/28/38.

Plus 14 Sight Records by Bingham and Miller, and Steele, including west fork Rapid River.

Penstemon wilcoxii Rydb. X either *P. attenuatus* Dougl. or *P. humilus* Nutt. (Lowly Penstemon). A possible natural hybrid.

C. Johnson Sight Record, Plot 999, ca. 75' northwest of rd. 1819 ca. 1/3 mi southwest of Cold Springs Cow Camp, 6,700', 7/1/83.

Scrophularia lanceolata Pursh, Lance-leaved Figwort.

Uncommon, central Seven Devils, 6,800-8,500'.

Bingham and Miller 253, ID and WS, northwest-facing, open, rocky slope with an open forb-grass stand, along trail 124 ca. 1 mi north of Horse Heaven Saddle at the bottom of the switchbacks in the head of the south fork of Devils Farm Cr., 7,800', 8/28/80.

Davis 2337, WS, sliderock on hillside of Sheep Cr. (prob. along trail 112), 6/26/40.

Henderson 3847, ID, along trail 112 near the bottom of the long, west-facing, talus traverse up out of the west fork of Sheep Cr. ca. 1/3 mi north of the Devil's Tooth, 6,800', 7/7/77.

Ownbey and Meyer 2073, WS, sliderock, headwaters of Sheep Cr. (prob. along trail 112), 6/26/40.

St. John and Mullen 8562, WS, rockslide on He Devil Mt., 8,500', 7/24/27.

Plus 3 Sight Records by Bingham and Miller, vicinity of Quad Lake, shores of Horse Heaven Lake, and vicinity of the jct. of trail 112 with the Sheep Lake fork of the west fork of Sheep Cr., 6,800-7,600'.

Syntheris missourica (Raf.) Pennell, Mountain Kitten-tails.

Frequent, entire Seven Devils, 5,000-8,100'.

Baker 11340, ID, moist banks 6 mi north of Cuprum (prob. along rd. 106), 9/3/53.

Bingham 325, ID and WS, and 470, ID, south-facing, half-shaded, rocky slope in a moderately dense *Abies lasiocarpa-Picea engelmannii* forest, ca. 0.1 mi up trail 214 from the Black Lake trailhead off rd. 112, 7,250', 7/17/81; and gentle, west-facing, 3/4-open, cutover forest with a deep, black, loam soil, ca. 0.1 mi northward along rd. 420 from Kirkwood Corrals, 5,050', 5/25/82; respectively.

?Brewer 11, Council R.D., Iron Springs Ranger Station (at the spring 0.2 mi north of Holbrook Saddle), sec. 12, T. 22 N., R. 2 W., 8,000', 6/24/28 (as *S. laciniata* (Gray) Rydb., a Utah species).

*Christ 11060, ?NY, under Douglas-firs and subalpine firs near receding snowline, Placer Basin, 5/30/40.

Lewis 1289, OGDF, open area near pass north of Horse Mt., 5,000', 6/16/67.

Packard 586, WS, north slope under open pine woods, Stormy Point, 5,900', 5/13/39.

Pennell 20808, WS, clefts in ryolitic rock, Smith Mt., 7,500-7,700', 7/9/37.

*Pennell 20816, ?PH, crevices on ryolite, Black Lake, 7,200-7,700', 7/9/37.

Wellner 1688, ID, north of the lookout on the summit of Pollock Mt., 8,050', 8/6/78.

Plus 4 Sight Records by Bingham and Miller, C. Johnson, and Steele.

Tonella floribunda Gray, Large-flowered Tonella.

Uncommon (mostly at lower elevs.), northern and southern Seven Devils and Rapid River, 5,000-5,600'.

Aldrich 7/05/07, ID 5113, Camp Howard (prob. the cow camp), 7/05/07.

Bingham and Miller Sight Records: along lower Rapid River trail 113 just below Blue Gulch, 2,550', 6/8/82; and along the same trail just above the main Rapid River forks in sec. 26, 2,700', 6/8/82.

*Christ 11065, ?NY, on mountainsides in Snake River Gorge west of Cuprum, 5/30/40.

Cusick 2227, WS, mountain near Cuprum, 7/10/1899.

Davis 2250, WS, moderately dry hillside, Grave Point Lookout, 6/24/40.

Holmgren and Tillett 10592, WS, in yellow pine forest 2 mi north of Cuprum, 6/22/54.

Verbascum blatteria L., Moth Mullein.

Scarce, lower Rapid River only, 2,300' ±.

Bingham and Miller Sight Record, along the lower Rapid River trail 113 ca. ¼ mi above the Circle C State Fish Hatchery trailhead gate, 2,300', 6/8/82.

Verbascum thapsus L., Common or Flannel Mullein.

Uncommon (mostly at lower elevs.), northern and central Seven Devils and Rapid River, 5,000-6,900'.

Bingham and Miller 587, ID and WS, open roadbed of rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,600', 8/17/82.

Bingham and Miller Sight Record: jct. of rds. 2060 and 1819 east of Low Saddle, 5,900', 7/10/81; McGaffee Cow Camp, 5,700', 8/12/81; along the lower Rapid River trail 113 ca. 0.1 mi above the Circle C State Fish Hatchery trailhead gate, 2,250', 6/8/82; along trail 113 ca. 1/3 mi southwest of Rankin Mill, 8/16/81; along rd. 2060 ca. ¼ mi east of Sawpit Saddle, 5,000', 7/8/81; along trail 101 ca. ½ mi northeast of Dog Cr., and along rd. 672 ca. ½ mi northeast of Cow Cr. Saddle, 5,300', 6/10/82.

C. Johnson Sight Record, Plot 990, above rd. 1819 in the head of Caribou Cr., 6,350', 6/28/83.

Veronica americana Schwein., American Veronica.

Uncommon, entire Seven Devils, 5,000-7,500'.

Bingham and Miller 251, ID and WS, flat, boggy streambottom in an *Abies lasiocarpa* forest, along the eastern creek from Ruth Lake and the Ruth Lake trail in a small bog ca. 0.1 mi northeast of Ruth Lake, 7,200', 8/27/80.

Bingham and Miller Sight Records: along rd. 1819 in upper Caribou Cr., 6,200', 7/10/81; in Horse Heaven Cr. ca. ¼ mi northwest of the Old Boise Trail, 7,300', 8/18/81; along the Sheep Lakes trail 123 in boggy areas just south of trail 112, 7,300', 8/13/81; along rd. 517 ca. ½ mi above its 2d crossing of Papoose Cr. in sec. 26, 4,900', 8/17/82; at Rankin Mill, 6,000', 8/16/81; at Hibbs Cow Camp, 7,450', 8/11/81; and along trail 124 in the south fork of th north fork of Little Granite Cr. ca. ½ mi south of Hibbs Cow Camp, 7,200', 8/10/81.

*Pennell 20798, ?PH, along cold stream and springhead, Smith Mt., 5,200-5,400', 7/9/37.

Veronica anagalli-aquatica L., Water Speedwell (European introduction).

Scarce, southern Seven Devils, 7,200' ±.

*Christ 8636, ?NY, shore of Black Lake, 8/8/37.

Veronica cusickii Gray, Cusick's Speedwell.

Scarce, central Seven Devils, 8,400' ±.

St. John and Mullen 8579, WS, creek bank on He Devil Mt., 8,600' (but there is no creek on the west side of He Devil, from which St. John and Mullen approached the mountain, at much over 8,400'), 7/24/27.

Veronica serpyllifolia L. var. *humifusa* (Dickson) Vahl., the dark-blue flowered variety of the Thyme-leaved Veronica.

Frequent, entire Seven Devils, 5,700-8,000'.

Bingham and Miller 35, 291, & 319, ID, in the open bog at the north end of the pond in the northeast corner of Sheep Lake, at the foot of the Goat Pass manway, 7,880', 7/22/79; open, southwest-facing, moderately moist rocky hillside along the Old Boise Trail ca. 7/8 mi south of the rd. 1819 trailhead southeast of Cold Springs Lookout, 6,740', 7/9/81; and along the northwest shore of Black Lake, 7,200', 8/17/81; respectively.

St. John and Mullen 8449, WS, streambank, Dry Diggins, 7,300', 7/20/27.

Plus 9 Sight Records by Bingham and Miller, McGaffee Cow Camp south to Towsley Spring, 5,750-8,000'.

Veronica serpyllifolia L. var. *serpyllifolia*, Thyme-leaved Veronica.

Scarce, central Seven Devils, 7,200' ±.

Christ 12635, ID and WS, marshy shores of Baldy Lake, 7/15/41 (this collection is intermediate with var. *humifusa*, fide RTB).

Veronica wormskjoldii Roem. and Schult., American Alpine Speedwell.

Scarce, central Seven Devils, 7,300-7,500' ±.

*Christ 12614, ?NY, grassy banks along creek, Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41.

Packard 427, WS, very moist high mountain meadow, "The Swamps" near Dry Diggins, 7,400' (actually 7,300'), 7/23/38; Lookout, *Festuca idahoensis-Agropyron spicatum* community, 5,550', 6/29/82; respectively.

Selaginaceae

Selaginella wallacei Heiron., Wallace's Selaginella.

Scarce, central Seven Devils, 7,600' ±.

Baker 12276, ID, open, gravelly slopes west of Seven Devils Camp, 7/31/54.

Sparganiaceae

Sparganium angustifolium Michx., Narrow-leaved Burweed.

Occasional, central Seven Devils, 7,200-7,500'.

Wellner and Bingham 1697, ID, along trail 129 in the shallow pond between Echo and He Devil Lakes, 7,500', 8/22/78.

Bingham and Miller Sight Records, in Baldy Lake, 7,200', 8/15/81; in Echo Lake, 7,200', 8/14/81; and in Lily Pad Lake, 7,300', 8/11/81.

Sphagnaceae

Sphagnum sp., Sphagnum Moss.

Uncommon, central Seven Devils, 6,000-7,300'.

8 Bingham and Miller Sight Records: shores of Bernard Lakes, 7,200', 8/11/81; 1½ mi north of the jct. of trails 140, 112, 57 at the Iron Phone, 7,300', 8/12/81; shores of Echo Lake, 7,200', 8/14/81; Rankin Mill, 6,000', 8/16/81; along trail 189 west of Ruth Cr., 6,800', 8/17/81; shores of Basin Lake, 7,300', 8/13/81; along trail 112 just east of the Sheep Lake fork of Sheep Cr., 6,700', 8/10/81; and along trail 124 just north of the Baldy Lake trail, 6,900', 8/15/81.

Taxaceae

Taxus brevifolia Nutt., Western Yew.

Occasional (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000-5,300'.

Bingham and Miller Sight Records: along the lower Rapid River trail 113 ca. ½ mi above Blue Gulch, 2,400', 6/8/82; and along the west fork Rapid River trail 113 near Cottonwood Cr., 3,500', 6/8/82.

C. Johnson Sight Record, Plot 790, above rd. 2060 just east of Kirkwood Cr., 5,300', 6/29/82.

Ulmaceae

Celtis reticulata Torr., Hackberry.

Scarce, lower Rapid River only, 2,200-2,400'.

Bingham and Miller Sight Record, *Celtis reticulata/Agropyron spicatum* h.t., open weedy grassland ca. ¼ mi up the lower Rapid River trail 113 from the trailhead gate at the Circle C State Fish Hatchery, 2,300', 6/8/82.

Urticaceae

Urtica dioica L. var. *californica* (Greene) Hitchc., the wide-leaved and hairy-stemmed variety of Stinging Nettle.

Frequent, entire Seven Devils and Rapid River, 5,000-7,600'.

Bingham and Miller 563, ID and WS, north-facing, half-open roadbank along rd. 517 ca. ¼ mi above its 2d crossing of Papoose Cr., 4,600', 8/17/82.

Bingham and Miller Sight Records: along trail 101 ca. 3/4 mi south of rd. 1819, 6,800', 7/9/81; along rd. 1819 ca. ¼ mi north of Caribou Cr., 6,200'; along trail 110 just east of McGaffee Cow Camp, 5,800', 8/12/81; along trail 58 ca. 1½ mi north of trail 112, 5,800', 8/18/82; along rd. 106 ca. 2 mi north of Lockwood Saddle, 7,000', 6/27/83; along rd. 105 at old Landore, 5,350', 6/30/82; along the lower Rapid River trail 113 just above the Circle C State Fish Hatchery trailhead gate, 2,200', 6/8/82; along trail 192 at Deb's Corral at the jct. of trails 192 and 189, 7,200', 8/16/81; along rd. 2060 ca. ¼ mi east of Sawpit Saddle, 5,000', 7/8/81; along trail 101 ca. ¼ mi east of Horse Heaven Saddle, 7,600', 8/19/81; along trail 124 in the south fork of Little Granite Cr., 6,700', 8/11/81; and along the west fork Rapid River trail 113 ca. 1¼ mi west of the main river forks in sec. 26, 3,300', 6/8/82.

C. Johnson Sight Record, Plot 791, above rd. 2060 ca. ¼ mi west of Lost Valley Cr., 5,100', 6/29/82.

Valerianaceae

Valeriana sitchensis Bong., Sitka Valerian.

Abundant, entire Seven Devils, 5,000-8,000'.

Aldrich 7/04/07, ID 5317, Camp Howard (prob. the cow camp), 7/04/07.

Baker 12032, ID, open alpine slopes, Seven Devils Camp, 7/21/54.

Bingham and Miller 108, ID and WS, east-facing, open creek bottom in a scattered *Pinus contorta* stand, in the northmost fork of Bridge Cr. ca. 0.1 mi north of Seven Devils Guard Station, 7,300', 7/14/80.

Brewer 25, Council R.D., head of Rapid River, sec. 20, T. 21 N., R. 1 W., 5,500', 7/28.

*Christ 8653, ?NY, in timber on lower slopes near Black Lake, 8/8/37.

Christ 12495, ID and WS, open coniferous timber, Seven Devils Camp, 7/12/41.

Q. Jones 206, ID and WS, near spring under *Pinus albicaulis*, Heavens Gate, 8/12/50.

Packard 335, WS, moist meadow near Hibbs Cow Camp, 8,000', 6/29/37.

Plus 54 Sight Records by Bingham and Miller, C. Johnson, Steele, and Tisdale.

Violaceae

Viola adunca Smith var. *adunca*, Early Blue Violet.

Frequent, entire Seven Devils, 5,000-7,600'.

Aldrich 7/04/07, ID 3472, Camp Howard (prob. the cow camp), 5,000', 7/04/07.

Moore 94, WS, ridge southeast of McGaffee Cow Camp, 8,600' (prob. nearer 6,000'), 5/16/36.

Packard 293 & 322, WS, moist woods near the left (prob. north) fork of Little Granite Cr., 6,800', 6/26/37; and moist mountain meadow, "The Swamps" near Lily Pad Lake, 6/28/37; respectively.

Plus 9 Sight Records by Bingham and Miller and C. Johnson, Cannon Cr. to Lockwood Saddle, 6,600-7,600'.

Viola adunca Smith var. *bellidifolia* (Greene) Harr., the caulescent- and glabrous-leaved variety of the Early Blue Violet.

Frequent, entire Seven Devils, 6,000-7,900'.

Bingham and Miller 30, ID, moderately moist banks of the pond at the northeast end of Sheep Lake at the foot and west of the Goat Pass manway, under an open *Abies lasiocarpa-Pinus albicaulis* stand, 7,880', 7/22/79.

Christ 12450, ID, crevices in moist cliffs above Seven Devils Lake, 7/11/41.

*Christ 12648 & 12712, ?NY, soil pockets on ridge between Sheep Cr. Lakes No. 3 and No. 4 (Gem and Sheep Lakes), 7/16 and hummocks in marsh about Lily Pad Lake, 7/17/41; respectively.

St. John and Mullen 8508, WS, grassy flat, Dry Diggins, 8,000', 7/21/27.

Plus 11 Sight Records by Bingham and Miller, Crater Lake south t Joes Gap, 6,000-7,800'.

Viola adunca Smith var. undet., Early Blue Violet.

Bingham and Miller Sight Records: along rd. 517 just north of th north fork of Shingle Cr., 6,700', 8/17/82; and along the west fork Rapid River trail 113 just below Cottonwood Cr., 3,500', 6/8/82.

Steele Sight Records: Stand 74-38, along rd. 517 below the south fork of Papoose Cr., 5,800', 8/8/74; and two stands (81-P1-01A and 01B), along rd. 105 ca. 6 mi north of Cuprum, 5,550', 6/24/81.

Viola canadensis L. var. *rugulosa* (Greene) Hitchc., Western Canadian Violet.

Occasional (mostly at lower elevs.), northern Seven Devils and Rapid River, 5,000' minus.

Bingham and Miller 490, ID and WS, northwest-facing, 3/4-shaded, mossy talus slope along the lower Rapid River trail 113 ca. ¼ mi above Blue Gulch, 2,450', 6/8/82.

Bingham and Miller Sight Records: along the stock-drive part of trail 104 ca. ¼ mi east of Big Canyon Saddle, 4,600', 6/11/82; and along the west fork Rapid River trail 113 ca. 1 mi west of the main Rapid River forks in sec. 26, 3,200', 6/8/82.

Viola macloskeyi Lloyd var. *macloskeyi*, Small White Violet.

Uncommon, central and southern Seven Devils, 7,000-7,800'.

Bingham and Miller 115, ID, open, level, silty-peaty bog in the small pond just north-northeast of Lower Hanson Lake and between the Lower and Upper Lakes, 7,750', 7/15/80.

*Christ 12612, ?NY, moist banks of Sheep Cr. Lake No. 2 (Shelf Lake), 7/14/41.

Henderson and Bingham 3864, ID, east shore of Baldy Lake, 7,200', 7/6/77.

Plus 6 Sight Records by Bingham and Miller, southeast shore of Baldy Lake, 7,200', 8/15/81; shores of Bernard Lakes, 7,200', 8/11/81; shores of Echo Lake, 7,200', 8/14/81; vernal pond east of the Old Boise Trail 101 just southwest of Horse Heaven Cr., 7,000', 7/19/81; along trail 123 just north of Basin Lake, 7,300', 8/13/81; and outlet of the largest Six Lakes Basin lake, 7,800', 7/18/81.

?*Viola nephrophylla* Greene, Northern Bog Violet.

Scarce, central Seven Devils and Rapid River, ?6,800' minus.

Bingham and Miller 166, ID and WS, in very rocky loam at the foot of a small outcrop, on a gentle, southeast-facing, 1/5-shaded slope with a sedge-forb meadow at the edge of a *Pinus contorta, Abies lasiocarpa, Picea engelmannii* stand in the bottom of Hanson Cr. ca. 0.1 mi east of the Old Boise Trail 101, 6,800', 7/17/80 (collection identity should be rechecked by an expert, since *V. nephrophylla* normally is a wet-soil and lower elev. species).

Bingham and Miller Sight Record, along the lower Rapid River trail 113 just below the main river forks in sec. 26, 2,600', 6/8/82.

Viola nuttallii Pursh var. *major* Hook., Nuttall Violet.

Occasional, lower northern and southern Seven Devils, 5,100-6,700'.

Bingham 467, ID and WS, and Bingham and Miller 515, ID, west-facing, half-open, cutover hillside in a *Pinus ponderosa-Pseudotsuga menziesii* forest in the Douglas-fir/ninebark h.t., ca. 0.2 mi southward along rd. 420 from Kirkwood Corrals, 5,120', 5/25/82; and northeast-facing, open, rocky hillside in a sedge-forb stand along rd. 108 along the Snake River - Indian Cr. divide ca. ¼ mi south of Lockwood Saddle, 5/30/82; respectively.

Bingham and Miller Sight Record, along rd. 672 ca. ½ mi north of Cow Cr. Saddle, 5,300', 6/10/82.

Packard 580, WS, under scattered pine in the draw above the north fork (prob. Clark's Fk.) of Sheep Cr., near Stormy Point, 5/13/39.

Viola orbiculata Geyer, Dark Woods Yellow Violet.

Abundant, entire Seven Devils and Rapid River, 5,100-7,400'.

Baker 16795, ID, 9 mi west of Riggins (5,100-7,400', prob. on McClinery Ridge along rd. 517), 5/24/65.

Bingham and Miller 136, ID and WS, gently southeast-sloping flat almost completely shaded under a dense *Abies lasiocarpa-Picea engelmannii* forest just south of Dog Cr. ca. ¼ mi west of the Old Boise Trail 101, 7,000', 7/16/80.

*Christ 12588, ?NY, on cliffs in cirque below Seven Devils Lake, 7/13/41.

Packard 339, WS, head of the left (prob. north) fork of Little Granite Cr. near Hibbs Cow Camp, 6/29/37.

St. John and Mullen 8532, WS, edge of woods, Dry Diggins, 8,000', 7/22/27.

Plus 37 Sight Records by Bingham and Miller, C. Johnson, and Steele, along rd. 2060 near Kirkwood Cr. south to Lockwood Saddle, 5,200-7,400', and west fork Rapid River.

Viola palustris L., Marsh Violet.

Scarce, central Seven Devils, 6,800-?8,500'.

Packard 341, WS, moist streambank near the head of the left (prob. north) fork of Little Granite Cr., vicinity of Hibbs Cow Camp, Dry Diggins, 6/29/37.

St. John and Mullen 8577, WS, boggy shore of Little Granite Cr. Lake (prob. one of the upper lakes in the Echo Lake chain), 8,500', 7/24/27.

Viola purpurea Kell. var. *venosa* (Wats.) Brain., the inland variety of the Purplish Yellow Violet.

Frequent, central and southern Seven Devils, 5,000-8,500'.

Bingham and Miller 55, ID, southwest-facing, half-shaded, rocky slope in an open *Pinus albicaulis* forest ca. ¼ mi northeast up the Goat Pass manway from the pond at the northeast end of Sheep Lake, 8,100', 7/24/79.

*Christ 12454, ?NY, talus slopes Seven Devils Lake, 7/11/41.

Moore 72, WS, rocky hillside along Bernard Cr. trail 110, 3 mi from Snake River, 5,000', 5/16/36.

Ownbey and Meyer 2087, WS, gravelly, exposed ridge, Hibbs Cow Camp, 6/26/40.

Packard 326, WS, rocky slope east of Lily Pad Lake, 6/28/37.

Peters and Moore 154, WS, conifer forest near McGaffee Cow Camp, head Bernard Cr., 5,000', 5/16/36.

St. John and Mullen 8460 & 8555, WS, gravel ridge, Dry Diggins, 7,000', 7/20/27; and rockslides on He Devil Mt., 8,500', 7/24/27; respectively.

Plus 9 Sight Records by Bingham and Miller and C. Johnson, Papoose Lake south to Lockwood Saddle, 6,500-8,000'.

U.S. GOVERNMENT PRINTING OFFICE:1987-773-039/41040

Bingham, Richard T. Plants of the Seven Devils Mountains of Idaho—an annotated checklist. General Technical Report INT-219. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987. 146 p.

The Seven Devils Mountains of west-central Idaho rise to almost 9,400 ft elevation, but occupy a very narrow strip of mostly Hells Canyon Wilderness lands lying between the Snake and Salmon River drainages. Plant taxa are checklisted for these mountains. Collections representing 722 taxa are annotated as to collector's names and accession numbers, herbaria where deposited, and locality, elevation, and habitat of the collection site. Data came from 2,700 collections found in seven herbaria, or from field collection notes of 13 different plant collectors.

KEYWORDS: plant checklist, plant distribution, botanical history, Seven Devils Mountains (Idaho)

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

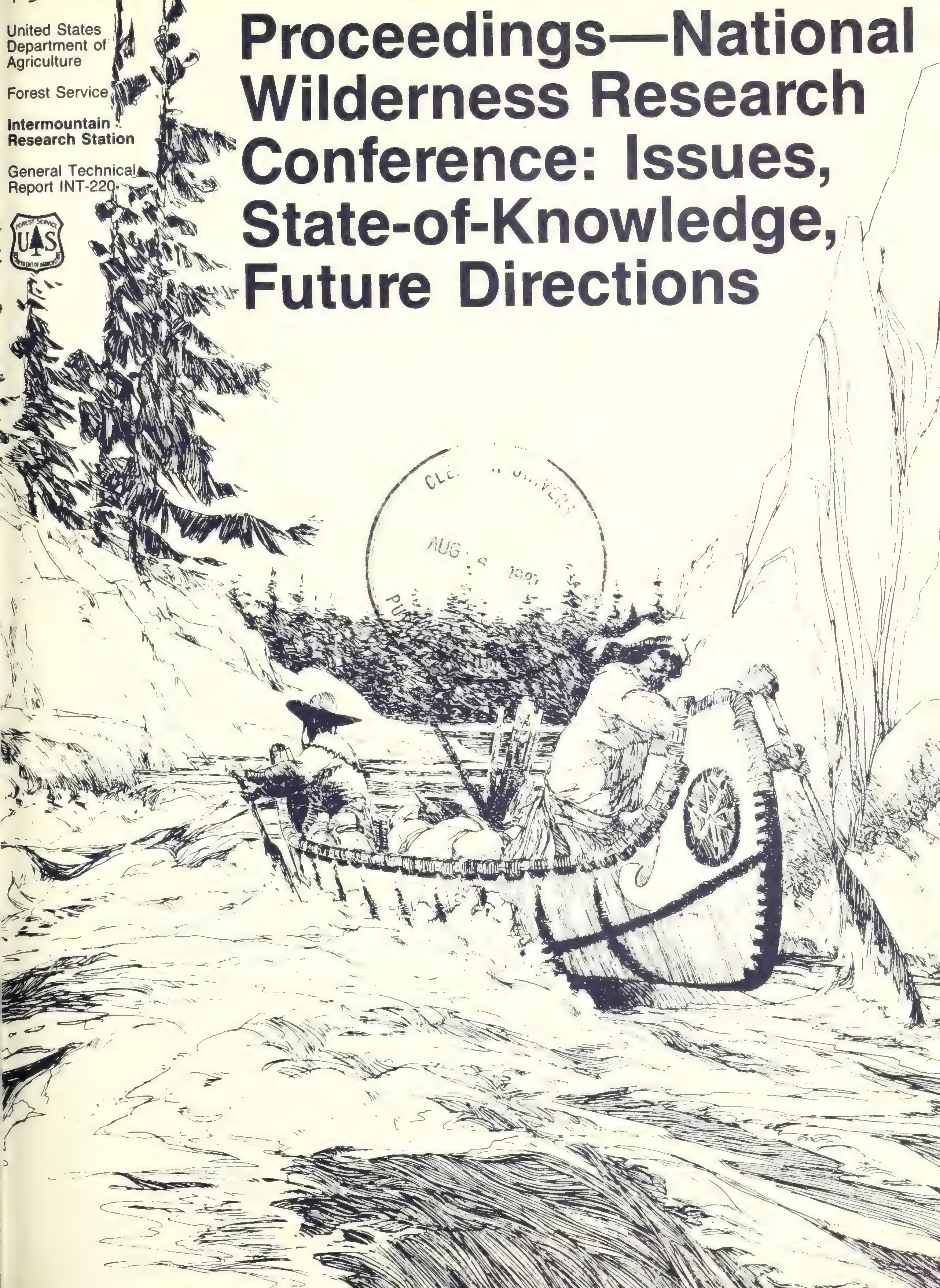
Forest Service

**Intermountain
Research Station**

General Technical
Report INT-220

Proceedings—National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions

CLE UNIVER
AUG 6 1987
PU



Statements by contributors from outside the U.S. Department of Agriculture are solely the views of the authors and do not reflect policies or opinions of the Department.

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

June 1987
Intermountain Research Station
324 25th Street
Ogden, UT 84401

Proceedings—National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions

Fort Collins, CO, July 23-26, 1985

Compiler:

ROBERT C. LUCAS, Project Leader, Intermountain Research Station, Forest Service, U.S. Department of Agriculture

Conference Sponsors:

U.S. Department of the Interior
  Bureau of Land Management
  Fish and Wildlife Service
  National Park Service
U.S. Department of Agriculture
  Forest Service
American Wilderness Alliance
Colorado State University
Oregon State University

Proceedings Publisher:

Intermountain Research Station,
Federal Building, 324 25th St.,
Ogden, UT 84401

FOREWORD

The National Wilderness Research Conference drew 400 people to Colorado State University in Fort Collins from July 23 to 26, 1985. The interest displayed by so many participants reflects the important values that wilderness has for Americans 21 years after passage of the Wilderness Act. In that time, the National Wilderness Preservation System has grown from 54 areas totaling 9 million acres to 445 areas and 89 million acres, and spread across the country, with a variety of settings, uses, and problems.

Which lands should be wilderness is still an important issue, but it cannot be the only concern. Protecting and managing the areas classified as wilderness is essential, and the difficulty of this critical task has become more obvious. Management was the focus of the conference, the first ever to concentrate on wilderness research. "Learning to preserve" was the conference theme, highlighting the need for research knowledge to advance our ability to manage wilderness effectively so it will fulfill the goals established in the Wilderness Act.

The long list of conference sponsors reflects the recognition of the importance of wilderness, its management, and needed research. Sponsors were: U.S. Department of the Interior, Bureau of Land Management, Fish and Wildlife Service, and National Park Service; U.S. Department of Agriculture, Forest Service; American Wilderness Alliance; Colorado State University; and Oregon State University. Their support was essential to the conference's success.

Wilderness also involves esthetics and humanistic values that go beyond science, and this side of wilderness was addressed by the 1985 Wilderness Art Exhibit, linked to the conference. Sixty very talented painters and sculptors displayed their works in a 3-day show tied to the research presentations.

Wilderness is a composite of many elements and has numerous uses. Its management is complex and must deal with a wide range of problems. The research conference structure reflected this complexity and breadth.

There are two proceedings volumes. The other volume presents over 70 offered papers reporting current research on nine topics, five dealing with wilderness resource research and four with wilderness user research. This volume includes invited papers that place wilderness values, management problems, and research needs in perspective; papers that review the state-of-research knowledge for the nine topics and provide directions for wilderness research in the future; a section giving a planning-application example; and a conference highlights paper.

We feel that the background perspective papers, including statements from leaders of all four wilderness-managing agencies, will be valuable to wilderness research scientists and managers in the future, as will the discussions of future research priorities. However, we think the nine state-of-knowledge reviews will be invaluable for many years. These are definitive summaries of past research, guides to the literature, evaluations of the coverage and adequacy of research on the topic, and suggestions of critical knowledge gaps.

The papers were written by leading authorities on each topic. They did an outstanding job and should be commended. The many people who thoroughly reviewed these long papers also deserve recognition. Without their efforts, the referee process would have been impossible. Scientists planning research in the future will use these papers as their starting point for wilderness studies of fire, air quality, visitor impacts on soil and vegetation, fish and wildlife, water, recreational use and users, attitudes and behavior, benefits, and visitor management concepts and tools. Managers will also turn to these papers, we hope, to strengthen their programs for management and protection of wilderness. There really is nothing else like these reviews available anywhere. We hope that the Wilderness Research Foundation announced at the conference can contribute to critical research needed to build on the current knowledge described in these nine papers.

The conference was lots of work, lots of fun, and definitely worth it all. I am glad we did it, but it will be quite a while before I am ready to take on the job again! The original idea for the conference came from Glenn E. Haas, College of Forestry and Natural Resources, Colorado State University. Mike J. Manfredo, Department of Resource Recreation, Oregon State University, Sally A. Ranney, President, American Wilderness Alliance, Glenn, and I were the planning committee. Colorado State University and their Office of Conference Services hosted the conference well. The beauty of the setting, with the Front Range of the Rocky Mountains as a backdrop, probably helped inspire the participants as they enthusiastically grappled with wilderness research issues.

Special recognition is deserved by Hollis Williford of Loveland, CO, who drew the cover illustration and generously donated it for use on the two proceedings volumes. The canoeists remind us of the time when most of the continent was wilderness. Hollis is also a Director of the Wilderness Research Foundation, so he is doubly supportive of wilderness research. We thank him greatly.

We hope the major beneficiaries of the conference will be the wilderness resource and the people who will experience it far into the future.

ROBERT C. LUCAS

Proceedings Compiler

CONTENTS

Page

Learning to Preserve
Sally A. Ranney 1

Section 1. Perspectives on Wilderness Values, Management, and Research 4

Wilderness Values and Challenges: A Colorado Perspective
David H. Getches 5

Congressional Perspectives on the Origin of the Wilderness Act and Its Meaning Today
Harry Crandell 9

Perspectives on the History of Wilderness Research
Robert C. Lucas 15

The Wilderness Research Foundation
Glenn E. Haas and Michael J. Manfredo 29

Research and Management: A Team for the Wilderness
Robert A. Jantzen 31

Managing Our Wilderness Heritage
Robert F. Burford 35

Wilderness Research: An Important Link to Wilderness Management
R. Max Peterson 37

The National Park System: The Challenge Ahead
William Penn Mott, Jr. 39

Scientific Use of Wilderness
Jerry F. Franklin 42

Scientific Issues in the Definition of Wilderness
George H. Stankey 47

Wilderness Policy: An International Perspective
Harold K. Eidsvik 54

Research Needs for Wilderness Management—An Update from the National Wilderness Management Workshop
Edwin E.Krumpe and William J. McLaughlin 59

A Framework for Wilderness Assessment and Research
H. Kenneth Cordell and Alan E. Watson 63

Section 2. State-of-Knowledge for Wilderness Resource Research 69

The Role of Fire in Wilderness: A State-of-Knowledge Review
Bruce M. Kilgore 70

Air Quality in Wilderness: A State-of-Knowledge Review
R. Kent Schreiber and James R. Newman 104

Research on Soil and Vegetation in Wilderness: A State-of-Knowledge Review
David N. Cole 135

Fish and Wildlife Research and Wilderness in the United States: A State-of-Knowledge Review
Edward E. Starkey and Gary L.Larson 178

Page

Water Resources Research for Wilderness: A State-of-Knowledge Review
Raymond Herrmann and Owen R. Williams 191

Section 3. State-of-Knowledge for Wilderness User Research 203

Wilderness Use and User Characteristics: A State-of-Knowledge Review
Joseph W. Roggenbuck and Robert C. Lucas 204

Attitudes Toward Wilderness and Factors Affecting Visitor Behavior: A State-of-Knowledge Review
George H. Stankey and Richard Schreyer 246

Wilderness Benefits: A State-of-Knowledge Review
B.L. Driver, Roderick Nash, and Glenn Haas 294

Evolving Concepts and Tools for Recreation User Management in Wilderness: A State-of-Knowledge Review
Perry J. Brown, Stephen F. McCool, and Michael J. Manfredo 320

Section 4. Future Directions 347

Environmental Protection and Preservation Research Priorities
A. Alan Hill 348

Introduction to the Wilderness Research Needs Panel
William A. Worf 351

Wildlife Research Needs in Wilderness Areas
Lynn A. Greenwalt 353

Questions for Further Wilderness Research
Robert E. Howard 354

Pitfalls in Wilderness Management—Let's Avoid Them!
Clifton R. Merritt 355

Institutional Research for a Democratic Wilderness Policy
Bernard Shanks 357

Wilderness Issues and Problems the Scientific Community Can Help Resolve
Steven Child 359

New Challenges for Wilderness Research
David E. Porter 361

Managing the Wilderness Resource with Knowledge: Important Wilderness Management Issues Needing Research
Ed Bloedel 363

Fish and Wildlife Service Wilderness Research Needs
Marvin L. Plenert 365

Six Categories of Needed Wilderness Research
Joyce M. Kelly 366

National Wilderness Research Conference Highlights
Paul C. Pritchard 368

LEARNING TO PRESERVE

Sally A. Ranney

Ladies, gentlemen, and colleagues. I am delighted to be here today, particularly to have the honor of opening this conference and setting the tone for the next 4 days of discussion and presentations. I am most pleased that you are here, and know I speak for the other conference coordinators when I say that we are very much looking forward to your valuable participation in the sessions ahead. The collective experience and information about wildland resources that you represent reflect the finest state-of-the-art knowledge available in the scientific, management, and conservation communities.

As I thought about my charge for today, I could not help but reflect on something someone told me a long time ago. I do not know who first said it, therefore I can't give proper credit. The statement is: "An idea, not coupled with action, will never become greater than the brain cells it occupied."

I submit this to you for consideration on the outside chance it just might be a universal truth. Even if it is not, it is, I believe, an appropriate statement with which to launch a conference dedicated to the advancement of ideas, knowledge, and research about wilderness—and dedicated to that next and most important step of taking research into action—management.

THE WILDERNESS IDEA

Wilderness is one of those omnipotent ideas that grips the mind, heart, body, and spirit which surfaces once or twice in the history of mankind and revolutionizes thinking. In the beginning it was a concept of land ethics, of man-nature relationships, a philosophy, a counterpoint to man's appetite to consume everything nature has to offer. It is the idea that eventually resulted in the masterwork we call the National Wilderness Preservation System.

The concept lingered in the thoughts of Aldo Leopold, Arthur Carhart, and Bob Marshall. With Carhart as a quarterback, Bob Marshall was able to run with the concept (along with the field data he had collected) toward the goal—a system of land areas on this continent that would remain forever wild. He took the idea into the next dimension—the dimension of action. His passion, fire, wisdom, and unwavering commitment along with Leopold's eloquence captured the vision of Howard Zahniser and others. After much struggle and debate, the National Wilderness Preservation System became a reality, a powerful and hopefully enduring statement of the idea.

Yet as the idea flourished, so did the challenges and problems it presented. The question, "How much wilderness is enough?" is still being debated. Some argue that it will never be answered other than subjectively, although I believe history will show we have answered it—and objectively. We need only to look at the statistics and see that we have already, in 200 short years, drawn on approximately 90 percent of our country's land bank principal.

However, because of this subjective debate and the opportunities of our pluralistic system, the movement to protect remaining wildlands within the National Wilderness Preservation System will be carried forward with a deep sense of urgency and patriotic commitment as long as there is 1 acre of wilderness left unprotected and one wilderness advocate still living.

SOUND FOUNDATION NEEDED

Equally as important as the tug-of-war to get areas under the protective umbrella of the Wilderness Act, is the management of these areas—management that has a foundation of sound research and data from which to draw.

If the purpose of the National Wilderness Preservation System is to remain justifiable and those areas under its protection are to truly retain their wilderness values, we must learn to preserve by effectively applying research to management, and we must develop an educated sensitivity about our stewardship responsibilities. These are the critical components for the long-term survival of the wilderness resource.

The challenges, opportunities, and needs presented by our unique, and I might add, internationally envied, Wilderness Preservation System truly belong to the spirit of America. This spirit of resiliency, independence, and ingenuity came from both opportunities and hardships we faced in our contact with the wilderness of this continent when we were an infant nation. And, by protecting the wilderness, we are taking a last stand for that which most precisely symbolizes what America is and hopes to always be.

But if the future of our wildland heritage is to be met successfully, it must be met skillfully, and collectively, by politicians, scientists, managers, educators, industry, conservationists, and the public, all of which are represented at this conference.

FOCUS ON SYNTHESIS

The cornerstone of this effort? The cornerstone is synthesis, and synthesis is the focus of this conference. We are here to share with one another what we have

---

Opening remarks presented at the National Wilderness Research Conference, Fort Collins, CO; July 23-26, 1985.

learned from wilderness and related studies and to explore management information needs requiring attention.

This opportunity has been made available to you in order to provide a forum where state-of-the-knowledge wilderness research can be presented, where integration and interpretation of what research has found related to wilderness protection and management can be investigated, and where communication can be facilitated.

The result will be the identification of future research needs that are in tandem with management needs, and bonds between people will be initiated or made stronger because it is people, not statistics, that get the job done. Our hope is that out of this conference will come some specific ideas about how ongoing communication networks, which are badly needed among all those represented here, might best take form and be funded.

At the same time we must acknowledge the fact that wilderness holds the answers to questions we still don't even know how to ask. Some might equate this statement with Murphy's Sixth Law of Experimental Procedure: "When working toward the solution to a problem, it is always advisable to have the answer first." Nonetheless it is true. We don't yet know all the answers wilderness may hold. There may well be a point in time when wilderness is the only biological and spiritual reference point from which changes in the rest of the world's environment can be measured.

Consider, if you will, that wilderness could hold more of the future of our planet within its boundaries, within its genetic pools, than we fully recognize or can even understand. If that is true, or even if it is not, the possibility mandates great care and a deeper sense of personal responsibility on our part.

In tangible terms, what is the magnitude and diversity of what we are dealing with? What should our priorities be in contemporary wilderness research and management?

GROWTH AND PROBLEMS

In 21 years, the National Wilderness Preservation System has grown from approximately 9.5 million acres to 89 million acres, a land mass 1.3 times larger than the State of Colorado and larger than a majority of the countries in the world. Some 60 million acres have been identified as still meeting the suitability requirements of the Wilderness Act and could be added to the System. Encompassed are some 455 areas, individually managed by four separate Federal agencies. Areas range in size from 6-acre Pelican Island off the Florida Keys to the 8.7 million-acre Wrangell-St. Elias Mountain Range in Alaska. Every ecosystem except the tall grass prairie is represented.

The Big Slough Wilderness in Texas and many small wilderness areas in the East are directly experiencing the impacts of management practices outside their legal boundaries.

In Florida we are faced with the problems of diversions outside wilderness that are affecting the freshwater drainage within the wilderness. Many wetland wildernesses in the South and Southeast are in a precarious ecological position because of activity that is impacting ocean and shell fish and waterfowl.

Along the Rocky Mountain Front, we are seeing the result of not protecting and managing the range of habitat needed by wilderness-dependent species such as the grizzly bear and bighorn sheep.

Alaska is facing different problems. Under the Alaska National Interest Lands and Conservation Act, the Natives were allowed to select and claim native corporation lands in new refuges, wildernesses, and parks. As a result, they own large inholdings, some as great as 100,000 acres. When these areas are contracted for development, the wilderness values and wildlife are affected, if not seriously threatened. The questions of allowing fly-ins to hunting cabins and the existence of the cabins themselves are subjects of heated controversy.

In desert areas, such as the Organ Pipe Wilderness in Arizona, we have only recently begun to understand the long-term effects of human activity. Deserts, along with the Arctic areas, are the most fragile of all ecosystems. For example, in the California Desert, the cat tracks of General Patton's 1940 tank maneuvers can still be seen.

In the chaparral country there is the question of how to manage fire. The siting of hazardous waste dumps (an item not even on the tip of Bob Marshall's mind), activities that impair air quality within wilderness, and the insidious and not-so-insidious effects of acid rain on pristine watersheds are now demanding attention. And we are still playing cat and mouse with carrying capacity.

Addressing research and management activities and needs both within and outside wilderness boundaries must be a top priority, or ultimately we cannot maintain wilderness. Wildlife, watersheds, and ecosystems do not recognize the artificial boundaries we have placed around our wilderness areas. By not addressing this situation, we are in essence confining our vision, like walking through the dark using a flashlight. Our eyes become accustomed to seeing only what is within the beam of light. Yet we obviously know we will have to deal with many other things out in the dark beyond the flashlight beam.

We need to look beyond the boundaries to construct a vision of how to best manage the wilderness within. We must look beyond the wilderness line on the map and beyond the Congressional Record.

By tackling this challenge, we are seriously testing our general environmental health. Wilderness is where the full circle of environmental integrity is complete. Consequently, we are questioning every environmental standard set to date, many of which we had a hand in establishing, in order to determine if wilderness is being compromised. We must also, in this process, evaluate whether changes are acceptable, and if so, determine the limits of change that can be tolerated.

There is and will continue to be much resistance on this front, and even some brawls, but the questions must be asked if we are to sustain a durable Wilderness System and if policy deficiencies are to be corrected.

As we all are too well aware, wilderness recreation demand and use have exploded. Depending on whose figures one uses, it has increased anywhere from 200 to 550 percent over the last 30 years. It is interesting that as long ago as 1898 John Muir noted that thousands of "tired, nerve-shaken people were beginning to find out that going to the wilderness . . . was like going home . . . that wilderness was a necessity."

Because recreation has increased so rapidly and has had to be faced head-on with immediate management strategies, the attention of managers and researchers has been drawn consistently in that direction.

BALANCE NEEDED

The balance between anthropocentric and biocentric research has been tipped toward the anthropocentric side of the scales. This has resulted in what I perceive as more subjective management approaches. These focus on how people view wilderness and the variety of the public's demands on wilderness rather than on more objective criteria founded on the facts of the physical and conservation values of the wilderness resource.

It is a difficult balance to maintain because we also recognize that the intangible resources of wilderness are no less important than the material resources. Unless we are willing to say that man's need for what wilderness and parks provide is as fundamental as his material needs, they are lost! The equilibrium must be regained between the two approaches.

Yet, I caution, as did Loren Eisley, that "in the pursuance of a future projected on science, we cannot leave the present to shift for itself." "Intelligent tinkerers," said Aldo Leopold, "save all the parts," and saving all the parts of wilderness is a challenge we must accept. There are many demands on managers, researchers, conservationists, and politicians coming from many directions.

The end result, however, of what we all do must be education. We must educate the public in this country so that each person becomes aware of and understands the wilderness environment and the future it holds. The education process must be done in such a way that the individual is helped toward developing a pattern of ethical and social behavior that reflects this understanding.

Research is critical to us as custodians of our wilderness resources. Research is the cog and management the wheel. Research is the steel hand within the velvet glove of management.

As we explore, exchange, and develop ideas in the next few days, we will become immersed in details and specifics. But let us not forget our broader purpose. What we call conservation, the ultimate of which is embodied in wilderness, is, according to Stewart Udall, "rooted in the needs of man's nature and his inner order of the universe. Conservation puts the future first and experience second."

Ladies and gentlemen, our work IS the future. We are on the leading edge. The next 20 years, indeed over this entire century but particularly in the next 20 years, we will see that what was perceived to be the far-fetched becomes the far-sighted. We are serving the collective challenge we face as trustees of our wildland heritage. We are unraveling the paradox of how to preserve and use wilderness at the same time. We are facing the challenge of defining and defending the rights of the wilderness resource for the sake of the resource itself and all the values it encompasses.

Thank you very much for being here. And welcome!

AUTHOR

Sally A. Ranney
President, American Wilderness Alliance
Englewood, CO 80112

Section 1. Perspectives on Wilderness Values, Management, and Research

WILDERNESS VALUES AND CHALLENGES: A COLORADO PERSPECTIVE

David H. Getches

ABSTRACT

Colorado is proud of its 2.6-million-acre wilderness system, which has great value in maintaining air and water quality, providing recreation opportunities, serving as wildlife habitat, and fulfilling human needs for solitude and reflection. American attitudes about wilderness have evolved from fear and hostility to appreciation and attraction. Today, wilderness has great economic importance. Issues include water rights, additional wilderness designation, and release language. Managers face many challenges in properly managing existing wildernesses, and also areas outside designated wilderness. Needs are to proceed with the designation process, manage wildlands in the best manner possible, and resist complacency about the existing wilderness system.

INTRODUCTION

I would like to welcome you to Colorado. It is appropriate that the National Wilderness Research Conference should meet in our State. Colorado attracts nearly 2 million wilderness visitors annually—about one-sixth of all wilderness visitors nationally. Our magnificent wilderness system includes 27 areas with a total of 2.6 million acres. An additional million and a half acres are being considered for wilderness designation.

We are proud of our wilderness lands, spectacular areas with colorful names that reflect our heritage—Eagle's Nest, Indian Peaks, Never Summer, West Elk, Maroon Bells—and candidate areas named Oh-Be-Joyful, Cannibal Plateau, and Sewemup Mesa. These wilderness areas provide us with matchless opportunities for recreation—hiking, hunting, fishing, wildlife viewing, camping and skiing, to name a few. They have incalculable value in helping to keep our watersheds pure, our air clean, and our wildlife insulated from increasing conflicting demands for land. They are living laboratories for research. And, perhaps most important, they are refuges where human needs for solitude and reflection can be satisfied. Even those who do not visit wilderness enjoy psychic benefits from the knowledge that wild areas are there. In short, wilderness areas are a major reason for the special quality of life we enjoy here in Colorado. Similar benefits are enjoyed in the 455 wilderness areas throughout the United States.

Fear and hostility of wilderness by early Americans whose mission it was to tame the wilds have yielded to modern attitudes of respect for our natural heritage. Alexis de Tocqueville observed that "Americans . . . are insensible to the wonders of inanimate nature and they may be said not to perceive the mighty forests that surround them till they fall beneath the hatchet." Americans of the early nineteenth century, according to Tocqueville, would "march across the wilds, draining swamps, turning the course of rivers, peopling solitudes, and subduing nature."

EVOLVING ATTITUDES

After the frontier closed, however, American attitudes evolved into widespread appreciation and attraction for wilderness. Roderick Nash, the noted American wilderness historian, who is with us at this conference, has written that wilderness appreciation is "one of the most remarkable intellectual revolutions in the history of human thought about land."

John Naisbitt, in his popular **Megatrends**, offers an explanation for the increasing tendency of people to seek out primitive forms of recreation. He says that we are experiencing the evolution of a highly personal value system. Perhaps it is an attempt to compensate for the impersonal nature of the technology that increasingly surrounds us. As technology skyrockets, so does the need to balance the spiritual demands of our human nature. As long ago as 1950, George W. Kelley, President of the Colorado Forestry and Horticultural Association, testified before a congressional committee that "wilderness areas have become a spiritual necessity, an antidote to the strains of modern living."

Today there is a broad base of public support for wilderness. Plainly, it has fit into our "national portfolio" as a long-term investment, a trust for future generations. Congress recognized this when it directed management of the public lands for multiple uses, purposes that include wilderness preservation and the attendant nonintensive uses for fish and wildlife habitat and recreation. Accepted public land policy favors permanent retention of lands with such resource values. Even some libertarians concede that government has a role, along with building roads and providing for national defense, in long-range protection of certain natural resources. The American wilderness enterprise has become a source of national pride and an example to other nations. It has succeeded without significant negative economic effects, and has actually proven to be a valuable economic asset for tourism and recreational uses.

Clearly, one of the reasons for the political attractiveness of wilderness has been its economic benefits. Recreation has become an economic mainstay for several western States where fortunes staked on resource development rise and fall with the mercury of industrial prosperity. Recently, tourism has been a safety net for Oregon as it despaired a decline in logging, and for mountain States such as Colorado, Idaho, Wyoming, and Utah as important mining industries and agriculture have been battered by national economics.

In Colorado, recreation and tourism is now the second largest industry, surpassing agriculture and mining. Tourism spending here exceeds $4 billion annually. As a whole, the tourism industry generated 100,000 Colorado jobs last year and produced $503 million in total tax revenues. And tourism is growing. The Colorado Tourism Board tells me that tourism has been at a record rate this year with the trend expected to continue through a bumper summer season.

GROWING IMPORTANCE

The quest for a wilderness experience is becoming increasingly important in meeting recreation demand. Colorado is known for its grand outdoors and vistas, its 54 14,000-foot peaks, its superb fish and wildlife, its blue skies, and its solitude. Many of these treasures are enshrined within wilderness areas. A visitor day to the wilderness in Colorado has been estimated by the Forest Service to have a value of $12.50. This represents the value to the user after the costs of Forest Service management and investment have been paid. Applying this figure to the number of wilderness visitors in 1984, wilderness use generated a net public benefit of $23 million in Colorado. This stands in stark contrast to the over $19 million lost in FY 1982, the most recent year of record, in timber operations in National Forests in Colorado.

The U.S. Forest Service has estimated that 1984 wilderness use in Colorado was directly responsible for generating 2,530 jobs and $71 million in revenues to the economy. It is also significant that 81 percent of existing Colorado wilderness areas and their related economic benefits occur in western Colorado where such benefits are sorely needed. While these economic advantages in no way adequately represent our primary reasons for wilderness protection, they are useful in justifying designation and preservation of the areas in a time of economic stress.

One of the earliest wilderness debates in this country was over the preservation of the Adirondacks. In 1873 advocates of preservation found that their idealistic appeals, based on esthetics, protection of wildlife, and a love of nature, fell on deaf ears. They succeeded only when they appealed to the self-interest of other New Yorkers and the political understanding of the New York legislature. Without sacrificing their idealism, they emphasized New York City's need for a safe, clean, and reliable water supply that the Adirondacks could assure. In response to these arguments, over 700,000 acres were preserved in perpetuity to the benefit of all.

If wilderness opportunities are to remain important in Colorado and throughout the country, more protected areas and innovative management are needed as overuse by enthusiastic crowds threatens to consume fragile wildlands. A 1982 Colorado State University survey done for the American Wilderness Alliance found nearly half of all Colorado residents favored doubling Colorado's wilderness acreage, and 36 percent of the population supported protection of all candidate areas in the State. The study found Coloradans apparently ready to pay for wilderness. The average Colorado family is willing to spend about $19 per year to preserve wilderness, simply to know such areas exist and will be protected into the future.

The results of a more recent poll were announced last week by a group called Volunteers For Outdoor Colorado. The importance of natural resources for recreation was similarly emphasized:

-97 percent of those polled rated the need to maintain State recreation and natural resources as important;

-93 percent believe there are strong economic reasons to do so; and

-86 percent of the people polled said they were willing to do something to help maintain these resources.

Colorado has traditionally been at the forefront of wilderness designation. We were fortunate in avoiding the acrimony and wasteful litigation that plagued many States following the Forest Service's RARE II process. Aggressive bipartisan work by our congressional delegation led to decisive action by Congress on the 1980 Colorado Wilderness Act. That act added 1.4 million acres of Colorado lands to the National Wilderness Preservation System.

A NEW ISSUE

More than 700,000 acres of additional wild areas have been proposed for wilderness designation. Last year a compromise proposal on which members of our congressional delegation had reached consensus on the boundaries of virtually all areas was stopped when a new issue emerged. The issue was whether and to what extent Federal reserved rights may exist in wilderness areas. The United States has never claimed such rights for wilderness areas. But reserved water rights have been claimed on a variety of other public lands—parks, military bases, forests—to help carry out the purposes of reserving the lands. Where they exist, reserved rights cast a cloud of uncertainty over private water uses that commence after the area is set aside for specific Federal purposes. Unquantified reserved rights make it difficult for those with water rights junior to establishment of a Federal reservation to know how valuable or extensive their own rights are. This can frustrate needed investment and development of other resources that depend on water.

Experts differ as to whether there are reserved rights in wilderness, but it would appear that the magnitude of potential effects would be minimal even if water rights could be and were claimed by the United States. To clarify the law and to avoid practical problems, attempts were made to resolve the water rights issue at the eleventh hour of last year's debate over further designation of Colorado wilderness. Compromise language was being drafted. However, the issue became polarized over a Sierra Club lawsuit seeking to force the Forest Service to claim reserved rights in the wilderness, so polarized that some interests shunned compromise attempts. And that is where we stand—with wilderness designations stalled on the reserved rights question.

In my mind it is essential that we proceed with additional wilderness designation to expand heavily used existing Colorado wilderness areas and to add some new areas in Colorado to the wilderness system. To do so the water rights issue must first be resolved. This is not a problem that rests with the Forest Service, nor is it solely a problem between water interests or wilderness advocates. It is an issue on which we can expect Congress to act only if we ourselves can first work out consensus solution acceptable to the diverse interests that are involved. Until we do, there will be no new wilderness established in Colorado. Furthermore, I fear that unless we resolve the issue soon, it no longer will be just a Colorado issue. Water rights are vital to other western States. The issue could complicate wilderness designation throughout the West. Thus, our solution to the problem must be a solution that will work generically. The wilderness reserved rights issue is a challenge that should be met by Coloradans in the first instance. I believe that language acceptable to all can be found, and I look forward to exploring the possibilities with all interests.

Colorado led the way in solving another national wilderness issue. Last year all wilderness designations were held up over the issue of what type of release language should be included for areas not designated. The approach finally adopted by Senator McClure and Representative Seiberling, which allowed new wilderness designations to proceed, was similar to language forged in the 1980 Colorado Wilderness Act. Thus, the 1980 Colorado approach to release was adopted for other States in 1984. I hope Colorado can similarly break a new trail to compromise over the reserved water rights issue.

OTHER CHALLENGES

There is another set of challenges facing us in managing our existing wilderness areas. Wilderness management is a dynamic process, and the issues and solutions are constantly evolving. Some of the most vexing are control of access by visitors, accommodating important scientific research, reconciling economic needs of those who have property rights within a wilderness, and protecting wilderness from incompatible uses on nearby lands.

Here in Colorado we are overusing several wilderness areas, including Indian Peaks, Maroon Bells-Snowmass, Eagles Nest, Holy Cross, and Big Blue. Wilderness worshippers make pilgrimages to these areas, then literally beat the wildness out of them with their Vibram. In response, the Forest Service has started a permit system to limit the number of campers and to disperse them throughout heavily used areas. At Maroon Bells, summer access is restricted to a shuttle bus system. Land managers are doing their best to fulfill a preservation mission. Yet, can the management regime itself torture wilderness out of existence? If you have to carry a pass in your pocket and camp in a designated site are you in the wilderness? If, as Nash has urged, wilderness is a state of mind, can we destroy it as readily with bureaucracy as with tractors?

Surely it is preferable in the long run to search for better ways to protect wilderness for future generations than it is to give our own generation the opportunity to be the last to enjoy it as wilderness. But if intensive management of designated wilderness drives people to now-pristine backcountry that is not designated as wilderness, those areas may be spoiled even as they await consideration for inclusion in the system.

An issue, recently resolved between the Environmental Protection Agency (EPA) and the Forest Service, involved the use of helicopters to sample western high-altitude lakes to evaluate potential acid deposition impacts. Use of choppers in the wilderness is ordinarily banned because the Wilderness Act of 1964 prohibits the use of motorized equipment. Ironically, carrying out a study in conflict with wilderness regulations could be critical to the future survival of wilderness lakes. As a result, the agencies recently agreed that EPA will take samples outside wilderness using helicopters and the Forest Service will sample wilderness lakes by ground access.

Owners of private, intermingled lands and patented mining claims continue to have access requirements which may conflict with wilderness intent. Conflicts require careful resolution on a case-by-case basis to ensure that legal rights of private parties are respected or compensated in accordance with law, while preventing damage to wilderness values. Unless private rights are observed and people affected by designation are dealt with thoughtfully, those within or affected by potential wilderness areas can be expected to object and to have their voices heard. If they are treated fairly, it will enhance the chances of expanding the wilderness system and establishing public rights.

A wilderness management issue of vital importance is how to manage areas **outside** designated wilderness. Obviously, the wilderness character of an area does not end abruptly at boundaries set by Congress. There is a continuum of natural features that should be expressed through the management of adjacent lands. Unless extraordinary natural features and habitats are protected, unless development and overuse is controlled near wilderness areas, the wildness of designated areas and their often equally attractive neighboring tracts is threatened. Where the buffer area is publicly owned, agency management and planning should be sensitive to the need to protect a wilderness continuum. Where the buffer area is privately owned, it is incumbent on the agency to work with local governments and property owners to sensitize them as to how wild values can be protected. Acquisition of conservation easements and development rights may be desirable.

MEETING RESPONSIBILITIES

State programs can also help protect unique geologic or biologic features and plant and animal habitat on both public or private lands. For instance, in Colorado we are especially proud of our Natural Areas Program. Since 1977, 47 natural areas containing more than 75,000 acres of land, much of it private, have been successfully designated and protected. Landowner participation is based upon voluntary cooperative agreements between landowners and the State; no areas are designated without landowner permission. The program serves us well in extending the wilderness continuum and increasing our capability to protect important natural features.

The pressures on our wilderness areas can also be met by improving the recreation potential of other lands. Nonwilderness areas in national parks, national forests, State parks, and other Federal and State public lands can relieve that pressure if they are managed and protected to allow dispersed recreation. It seems clear that the hunger for a backcountry experience is not limited to specifically designated wilderness areas. It can be satisfied by properly managed Federal, State, and local recreation areas. But this requires a commitment to manage such lands, at least in part, to sate the thirst of those seeking an outdoors experience that otherwise might have to be quenched by drawing on designated wilderness areas.

An overriding issue at this conference is: How can land managers meet the heady responsibility of protecting our precious wildernesses for future generations? Your mission is frustrated by the meager Federal budgets for wilderness management. We in Colorado are troubled that only 8.5 percent of the National Forest System budget is allocated to recreation. And only about 6 percent of that amount is earmarked for wilderness management. Vital work of the Wilderness Management Research Unit has suffered a 90 percent cut in recent years. Can the challenges of the future in wilderness management be met if wilderness managers are kept in poverty?

In summary, our challenges are many. Said another way, our opportunities are great.

- First, we need to proceed within an increasingly complex wilderness designation process to ensure that additional lands are set aside to remain part of our wild national heritage. If we are to succeed in the West we must pursue new approaches to the question of Federal reserved water rights.
- Second, wildlands will not stay wild without management. We need to manage our wilderness lands in the best manner possible to retain and enhance the essential values that led us to preserve them. At the same time we must allow public access to fragile lands in ways that will not destroy their character. Greater financial resources are needed to allow us to meet high management standards.
- And, finally, we cannot become complacent with the wilderness system that is in place. Wilderness represents only a portion of the natural continuum. As development presses in, we must continue to manage an array of natural lands, recognizing that all public land management decisions have a direct or indirect effect on wilderness.

These are the challenges ahead if wilderness is to have a permanent place in a changing world. Wilderness managers must play in a game dominated by economics and politics, where seemingly crass tradeoffs are regularly made. Aldo Leopold said:

> Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher standard of living is worth its cost in things natural, wild and free.

Today our society has begun **not** to take wild things for granted. Wild things have economic value as well as spiritual value. Wilderness managers can and must participate in the economic and political decision making on economic and political terms. And they can succeed.

I look forward to the ideas and insights of other speakers during this conference as we search together for the means to be better stewards of our wilderness resource.

AUTHOR

David H. Getches
Executive Director
Colorado Department of Natural Resources
Denver, CO 80203

CONGRESSIONAL PERSPECTIVES ON THE ORIGIN OF THE WILDERNESS ACT AND ITS MEANING TODAY

Harry Crandell

ABSTRACT

The Country's population growth and movement continue to change political institutions, including Congress. Congress does not initiate actions, but reacts, especially to public issues, and always attempts to achieve consensus. In wilderness legislation and designation, compromise to satisfy various interest groups often stimulates boundary adjustments resulting in less acreage being designated than was originally proposed. Management agencies have misinterpreted the intent of legislation, making it difficult to propose and designate wilderness. For the National Wilderness Preservation System to be maintained, an active, articulate citizenry must speak out in defense of untrammeled wilderness.

INTRODUCTION

As a 1950 graduate of Colorado State University (then, Colorado A & M), I cannot tell you how happy I am to be back on the Aggie campus. The last time I saw this campus was 25 years ago when I was here interviewing students for possible placement with the U.S. Fish and Wildlife Service. Obviously, the University has changed a great deal since then. But that fact should not come as a great surprise, because we live in an era of accelerating change which has had (and is having) tremendous influence on our thinking, lifestyles, and political institutions. As a preamble to a discussion of the U.S. Congress and how it views wilderness, I shall discuss two important factors which have been, and are, major influences of change.

POPULATION MOVEMENT

In 1941, President Franklin Delano Roosevelt stated that there are four essential freedoms:

- Freedom of speech...
- Freedom of religion...
- Freedom from want...
- Freedom from fear...

But Roosevelt did not mention another freedom; a freedom that is a singular American right; a freedom guaranteed by the Constitution; and a freedom taken for granted by us all—freedom of movement.

Americans can move anywhere in the Country they choose, whether it be job related, a family vacation, or simply a trip inspired by a desire to see what is on the other side of the mountain. We do so without fear of retribution and with no legal restrictions. For example, my wife and I drove here from Virginia. We traveled about 2,500 miles through eight States, and not once were we stopped and required to show identification papers or required to request permission to cross a border or subjected to any of the other checks that citizens of most other countries take for granted.

The population shift since World War II is the largest American exodus since the pioneers moved westward to settle the land and tame the wilderness over 100 years ago. And the shift is not to western States alone—Virginia, Georgia, North Carolina, Texas, and others have seen tens of thousands of newcomers take up residence.

POPULATION GROWTH

An allied factor influencing political decision making is that the population has nearly doubled since FDR's speech 45 years ago. This population increase has led to a tripling—some economists estimate a quadrupling—of per capita consumption, leading to the highest standard of living in the World. Thus, the consumptive and nonconsumptive demands on our public lands have increased to a point that would have been unthinkable even a decade ago.

To summarize, the Country's population growth and shifting patterns of that growth have changed—and still are changing—political institutions at all levels of government and have changed the manner in which these institutions deal with issues such as wilderness.

THE CONGRESS

The U.S. Congress is not an inanimate body. It is composed of 535 independent individuals with 535 different points of view. Each member has strengths, weaknesses, and prejudices like anyone else. With the exception of education level (most are lawyers) and a charge to represent their constituencies (which influences their daily decisions), members are a microcosm of the people of the Country as a whole.

In addition, the Congress is not an initiating body and, thus, is not a decision-making institution, nor does it play a leadership role in problem solving. The Congress reacts, seldom initiates, and, more often than not, is very slow to respond to change; be it change in public attitudes (such as civil rights) or economics (such as recession or inflation) or Presidential recommendation (such as cutting Federal expenditures). This is true regardless of party affiliation.

The Congress swings into action once an issue is joined whether it be loud and sustained public outcry where large numbers of their constituents are involved (the recent overriding of the Administration's budget proposed to reduce Social Security benefits is an example) or enacting legislation during times of crisis (such as declaring war).

Even in times of crisis the Congress attempts to achieve agreement among its membership, where "majority rules." In the normal legislative process, the name of the game is "consensus" where agreement is reached through negotiation and "give and take" and the majority agree, while at the same time protecting the rights of the minority.

The Wilderness Act itself reflects most clearly the result of the consensus process. It contains conflicting management direction; for example, agencies must preserve the wilderness character of an area (Sec. 2(b)), while at the same time allowing the continued use of motorboats and aircraft (Sec. 4(d)(1)) and livestock grazing (Sec. 4(d)(4)). This has caused difficulty in developing management policies and, in a few cases, managers have thrown up their hands in despair and let the courts decide "what Congress meant."

It took 8 years for the Wilderness Act to become law. That action did not occur until there was a ground swell of public opinion and Congressional members saw that a vociferous segment of their constituencies, mainly private citizens, was in favor of such a law. On the other hand, a significant number of their constituents, mainly representatives of industry, were opposed to such a law. Conflicting language, intending to make everyone happy, was the inevitable result. But the consensus process did indeed work, and the Wilderness Act is the law of the land.

Wilderness areas are never designated by the sole initiative of the Congress. All units have been incorporated into the National Wilderness Preservation System (NWPS) by action of the Congress only on the recommendation of outside forces. Wilderness units established by the Wilderness Act (and the Wilderness Act itself) were the result of a broad spectrum of citizens pressing Congress to enact the Wilderness bill. Subsequent additions to the NWPS have been in response to the review requirement specified by the Wilderness Act; recommendations by the Forest Service resulting from RARE I and RARE II (in settlement of a court case, incidentally, not a Forest Service initiative); and as a result of local citizens (constituents) bonding together and voicing their opinion to their elected representatives in both the Senate and House.

Even though recommendations have been made, it often takes the authorizing committees of the Congress months or even years to come to grips with the wilderness proposed, partly because of scheduling difficulties, but usually because the hands of a committee (where the legislative action begins) are tied until it has before it a referred bill to consider. Someone has to introduce a bill before a committee can act! Usually, but not always, courtesy requires that a member representing a State or district in that State should be the bill sponsor. Most members are reluctant to stick their necks out and sponsor a bill unless there is an indication of public support for it in advance. Thus, the system has an inertia built into it, based on caution and an acquiescent public. These are the prime reasons that a number of wildlife refuge and National Park wilderness areas, recommended by the President over 10 years ago, are still waiting review by the Congress. Caution and diverse and changing opinions expressed at the grassroots level are the main reasons that most of the RARE II recommendations took several years to enact.

The bulk of the NWPS is located in the public land States, a section of the Country in which most local people have opposed wilderness designations because of fear of change and "lock-up" of resources. While most people in rural communities still oppose wilderness, a majority of urban dwellers do not. A changing attitude (votes) is a direct result of a population shift to the West. Those thousands of people freely moving from States where private land dominates and access is very restricted support wilderness because of opportunities, at last, to enjoy unhindered freedom of movement that the public lands and wilderness furnish. These people not only enjoy the free access that all public lands provide, but they voice their opinion to their elected representatives and, more important, vote!

After a wilderness bill has been introduced and a committee chairman decides to initiate action (usually in the form of public hearings) a significant number of forces are brought into play, not the least of which is a constant debate among the affected politicians as they try to define and redefine the term "wilderness" and its management for their own, sometimes very narrow, purposes. And the argument is not limited to politicians, as the wilderness management agencies, conservationists, industry representatives, and officials from all levels of government testify and lobby, arguing for their own definition or interpretations of wilderness in the form of recommending boundary modifications and management "exceptions" to accommodate diverse needs or uses. Arguments vary dramatically, depending on whether the witness is "for" or "against" wilderness.

We are all products of our own experiences. Even though the Wilderness Act established a new policy direction for public land management, wilderness, like beauty, is in the eye of the beholder. Individual experiences and beliefs have a significant impact on wilderness designations and are not limited to witnesses at hearings, agency personnel, or lobbyists. Members of Congress and staff, usually with little or no knowledge of public land management, impose their own view of wilderness, often with unsatisfactory results. For example, members of Congress will state that a wilderness ought to be "unique" or "beautiful." This belief, usually posed in the form of a question directed at a witness, is rooted in an antiwilderness bias and is intended to set the stage for boundary adjustments or elimination of the area altogether. Of course, neither word is in the Wilderness Act and neither should have a bearing on whether an area is qualified for entry into the NWPS. Too often, however, the high mountain country is a new and thrilling experience to non-Western members and staff (and to recently arrived citizens of a western State as well). Because peaks and rugged terrain are "unique" or "beautiful" to them, their wilderness establishment goal becomes "to save" that part of a wilderness proposal least likely to suffer intrusion. I have in mind here the areas that were included in the Colorado Wilderness Law of 1980 where the bulk of the acreage is above timberline. In order "to save" these "unique" and "beautiful" areas, wilderness proponents fall into the trap carefully set by the antiwilderness forces and agree to boundary adjustments eliminating lands at lower elevations, much more threatened by development than the high country.

Since the legislative process is a consensus process, focusing on boundaries and total acreage, impact on the size of individual wildernesses often is considerable as smaller wilderness units than those originally proposed emerge for the President's signature. Or, if not smaller, with more acreage above timberline than originally proposed, replacing critical watersheds and wildlife habitats at lower elevations.

Why should this be? Why doesn't the Congress just rubberstamp an agency proposal? For example, why hasn't the Congress merely accepted the Forest Service RARE II recommendations? The answer, my friends, is that the overriding legislative goal is to achieve a consensus among competing interests and, thus, among Congressmen themselves. A simplistic description of some of the interest groups would be: The forester believes that trees must be "managed" and the only good tree is one that can be reduced to lumber or pulp; thus, the timber industry lobbies for wilderness boundaries that contain a minimum of trees, crying all the while that lost jobs (meaning votes) are at stake. The western water interests believe that every drop of water should be destined for consumptive use, like watering lawns, and lobbies for minimum boundaries so that future water "development" ideas are not foreclosed. Wildlife managers believe that opportunities for future habitat manipulation, intending to maximize huntable wildlife populations, must not be foreclosed and lobby for assurances that future "management options" will not be forgone. The minerals industry, inferring that the country could be going down the tube because of dependence on foreign mineral sources, lobbies for large exclusions on the speculative grounds that a mother lode of some mineral might be found there somehow, someday. And the wilderness users, particularly the newer recruits to a State, believe that a wilderness area is a recreation area alone and their exclusive province and lobby "to save" the most spectacular, mosquito-free part of a wilderness proposal (meaning high-altitude peaks). Even the Forest Service lobbies for and against changes in its own wilderness proposal, which usually was the minimum to begin with.

The consensus process throws all of these competing forces into the legislative pot, stirs mightily, and adds ingredients represented by the off-road vehicle interests, stockmen, highway departments, local politicians, hunters, and anglers. Add those who prefer to drive their pickup to the site (translation: access) and the emerging wilderness is a much different stew than when the process began some months, or even years, earlier. The spice ingredient of the stew is the fact that members very seldom "roll over" the representative of the district in which the wilderness is located. So there is usually more give than take during the process unless the representative is a strong wilderness advocate, which is seldom.

WILDERNESS MANAGEMENT

For many years there was little direction by the Congress relative to managing an area once it was placed in the NWPS by law. The Wilderness Act, of course, is flexible in nature regarding qualification standards for entry into the NWPS, but more stringent regarding management afterward, except for certain "special provisions" in the law, the applicability of which is not universal.

The initial review standards established by the Wilderness Act required the U.S. Forest Service to review and make recommendations, within 10 years, concerning wilderness suitability or nonsuitability of already established primitive areas. The law did not bar review of other National Forest lands, so RARE I and RARE II were not in conflict with the intent of the Wilderness Act even though the Forest Service was forced to review roadless lands adjacent to primitive areas and roadless lands in general because of court decisions on lawsuits filed by conservation organizations. The National Park Service and U.S. Fish and Wildlife Service were required to review all roadless areas of 5,000 acres or more. The Fish and Wildlife Service also was directed to review all roadless islands.

The Forest Service review mandate required little interpretation because the areas were already established administratively (except for enlargements to or a deletion from a primitive area which were under consideration), but considerable debate occurred in the Interior Department as it wrestled with defining "roadless area," "roadless islands," and "wilderness." The Department finally applied the definition in Sec. 2(c) of the Wilderness Act to the latter. While the Forest Service promptly moved forward with its review of primitive areas, the Interior Department, displaying a deep antiwilderness bias, took over 2 years to issue draft regulations, which were required before the review process could proceed. Even so, all three of the wilderness agencies confused the entry standard of Sec. 2(c) with wilderness management provisions of Sec. 4 and are continuing to do so to this day. The latest arrival on the wilderness review and management scene, the Bureau of Land Management, has fallen into the same trap. Considerable delay in conducting reviews, controversy over proposed boundaries, and citizen lawsuits have resulted, mainly because of a tendency to misinterpret these criteria in a most restrictive manner.

The Forest Service, for example, insisted for years that there should be no noticeable works of man in or near a potential wilderness area. And the Agency persisted in this purity point of view even though the Congress, responding to citizen concerns throughout the Country, enacted the so-called Eastern National Forest Wilderness Law of 1974, trying to restate the notion that public land areas which had "felt the hand of man" could indeed be classified as wilderness if left alone to regenerate. The Forest Service persisted in the West, however, applying such strict standards of purity that virtually no roadless area would qualify as wilderness. Again, the Congress stepped in, again at the urging of conservationists nationwide, and enacted a law. The Endangered American Wilderness Act of 1978 struck down the belief that the works of man need not be entirely unnoticeable within or adjacent to a roadless area, but merely be "substantially unnoticeable" as stated in the Wilderness Act. That law also addressed certain uses that the Forest Service felt were not compatible with wilderness. Why should it be necessary for the Congress to get involved at all in these questions? Shouldn't the guidance provided by the Wilderness Act be sufficient? Obviously not.

Yet, the problem is not with the Wilderness Act itself. The problem is in the minds of people charged with the responsibility of either making the initial identification of a potential wilderness area for review, or in developing management programs afterward. The Wilderness Act is flexible enough to accommodate a wide range of opinions, ideas, and interpretations. Policies are nothing more than ideas put on paper and distributed throughout agencies for management guidance. As such, they are subject to change.

Again, we all are products of our individual experiences, and the perceptions and experiences or lack thereof of people in positions of authority dominate policy formulation, which, in turn, causes these misinterpretations of the law to become national policy. For example, the word "untrammeled" was carefully selected by Howard Zahniser, drafter of the wilderness law, to reflect a wilderness condition of being "left to operate freely." But, untrammeled has been misinterpreted by Forest Service wilderness review teams to mean "untrampled." When coupled with an interpretation of "substantially unnoticeable" to mean "unnoticeable," this has caused thousands of acres of roadless lands to be summarily dismissed from further consideration as wilderness. The Congress, responding to appeals by conservationists, has consistently overruled these misinterpretations of the law and has placed lands in the NWPS that the Forest Service had previously rejected. While "untrammeled" is an entry guide, it is frequently utilized as a management guide as well, which has led to all sorts of problems when defined as "untrampled."

The overriding management direction of the Wilderness Act is found in Sec. 4(b), which directs agencies "to preserve the wilderness character" of wilderness units under their administration. Yet, to my knowledge, none of the wilderness management agencies has ever tried to document the exact combination of ingredients composing the wilderness character of individual wilderness units in order to develop management standards intending to preserve the wilderness character of each unit. And that lack of documentation is the crux of the wilderness management argument and is the reason why there is an increasing number of symposia and conferences in which "wilderness management" is the focal point.

In summary, agency management policies are developed on a national scale, applying equally to all wilderness units, regardless of ecological condition or location. Yet, wilderness areas are like fingerprints, each differing from any other, even though some are located in close proximity. Management policies must be developed on an individual unit basis, within a broad national policy framework. The present method of attempting to develop detailed policies applicable to all wilderness units equally simply has not worked and should be shelved until the wilderness character of each and every wilderness area has been researched, documented, reviewed by the public, and approved.

THE FUTURE

What does the future hold for the National Wilderness Preservation System and its management? While nobody can predict the future with finite accuracy, there are trends present today that might provide a clue.

1. *Population Growth.*—Despite a relatively low birthrate, the Country's population will continue to grow, placing greater and greater demands on natural resource utilization. Thus, the setting aside of areas of the public lands as wilderness will become increasingly difficult unless a larger percentage of the public develops awareness of the value of the preservation of natural places for the future. The point here is that without a continual growth in the numbers of people speaking out for wilderness designations, it is unlikely that the Congress will be very anxious to designate very many of them.

2. *Population Shifts.*—Demographers are predicting that the relatively recent population shift to the West and Southwest will decline in terms of percentage of the population as a whole because of the lack of jobs, primarily. Another constraint, as time passes, might be the lack of water in some States to maintain the "quality of life" that most people have come to expect. This means that there could be fewer local people (percentagewise) interested in preserving new wildernesses or protecting and defending local units of the NWPS from intrusion.

3. *Freedom of Movement.*—While the freedom to move about the Country at will won't change, freedom to move about the public lands, especially wilderness areas, will be restricted, as it should. Human impacts on some wilderness areas (such as Indian Peaks south of Fort Collins) are already so severe that they would not qualify today for entry into the NWPS because primeval character and influence, solitude, and a natural condition have been sacrificed. Further, the Forest Service doubtless is in violation of the intent, if not the spirit, of the Wilderness Act because these heavily impacted units simply are not being left unimpaired nor is their wilderness character being preserved. Certainly, none of them is "untrammeled," but, rather, they are being "trampled" to death by a well-meaning, but chest-thumping, freedom-of-movement endowed, public.

Why are some wilderness areas being loved to death? Close proximity to huge urban centers, ease of access, and size are important factors, of course. But the primary reason that the purposes of the Wilderness Act are being subverted is the dramatic change in public attitudes toward wilderness in the past 10 to 15 years. The bulk of the public now views wildernesses as being primarily (and perhaps solely) recreation areas, open to all who have the means to get to them. This significant change is the fault of no single institution, but is the sum of a combination of changing organizational and individual attitudes toward wilderness.

The founders of the wilderness movement had an ideal in mind, conditioned by their own individual experiences. For example, Robert Marshall, a hiker, viewed wilderness from a lonesome, solitary, seeking-solitude point of view; Aldo Leopold viewed wilderness as a natural, wildlife habitat preservation area where man hunted, fished, and viewed wildlife on natures's terms; Harvey Broome viewed wilderness as a means of restoring and preserving the natural scene with the Great Smoky Mountains as his example; Benton McKaye, a land-use planner, envisioned wilderness as a place for urban dwellers to seek renewal, alone, in a natural setting; and so on. None, of course, in the 1930's could predict the subsequent tremendous population growth, the huge exodus of people to other locations in the Country, the 40-hour (and less) work week and the resulting increase in leisure time available to the so-called working man; and none could predict the exponential growth in outdoor types of activities. Nevertheless, the Wilderness Act is clear that recreation is one (among five) of the public purposes to which wilderness areas are devoted (recreation is an equal, not a primary, purpose), all of which are conditioned by the Sec. 4(b) directive "to preserve the wilderness character of the area." The wilderness management agencies, especially the Forest Service, have failed miserably to meet this mandate of the law.

The only course left to agencies is to place severe limits on the number of people who can use a wilderness area in a given point of time. Public use should be governed by first determining the wilderness character (what are we charged with preserving?) and then managing public use to fit it. Many people will resist such a change as interfering with their freedom of movement, but such action is inevitable if wilderness, as defined in the Wilderness Act, is to survive beyond the present generation of users.

One might ask, why hasn't the Congress provided leadership in this area of concern? One reason is that the Congress has been preoccupied with placing units into the NWPS. Another reason is that there has not been a public outcry on this subject, and there may not be until the issue of overuse virtually starts to destroy certain wilderness areas.

4. *Defending the Wilderness System.*—Citizen conservationists will be faced with a formidable task in the future—defending units of the NWPS (and the system itself) from intrusion and subsequent downgrading to a point where a wilderness area is wilderness in name only.

Already signs leading to this unfortunate situation are becoming more apparent. It has been only through the resistance of the Congress that proposals advanced by special interest groups thus far have been modified or rejected.

As we have seen, since 1968 the Congress has focused on correcting the "purity doctrine" of the wilderness management agencies, particularly the Forest Service. Virtually every Committee Report on a wilderness bill contains a directive to an agency concerning boundaries which were adjusted, inclusion of the works of man, permitted uses, and so on. In each case the focus has been on a "management exception," in the view of the agency. Only rarely has a clarification been placed in the law. The so-called Eastern Wilderness Act and the Endangered American Wilderness Act were enacted partially to alleviate the frustration of members who felt that they were being asked over and over again to solve a management dilemma which had been solved previously.

In the late 1970's it became apparent that, despite committee report language to the contrary, the Forest Service was overly restrictive in its interpretation of the Wilderness Act's mandate that previously existing livestock grazing would continue. In the RARE II process, operators became extremely concerned, fearing that livestock either would be gradually phased out of wilderness or operations would be so restricted that continued use would not be feasible. Tired of seemingly always having to address this issue on a piecemeal basis, the Congress responded to these concerns by enacting the Colorado Wilderness Bill in 1980 in which report language, applying to all National Forest areas, was referenced and mandated in the law. The intent of this approach was to clarify the intent of the Congress when the Wilderness Act was being debated some 20 years before, and a compromise to permit previously existing grazing to continue was agreed to.

Clarification of the intent of Congress relative to language in existing law is a horse of an entirely different color than the demands of other special interest organizations. Not being satisfied with boundary adjustments by the Forest Service or the Congress to accommodate their concerns, bicyclists have requested that the Wilderness Act be reinterpreted so that bicycles are not "mechanical transport"; off-road vehicle enthusiasts have asked that snowmobiles be made an "exception" to the prohibition on use of motor vehicles, claiming that such use would be compatible with wilderness because the season of use occurs during that part of the year when all other uses are nonexistent; livestock interests have demanded that language be included permitting predator control programs to continue in wilderness; boundary adjustments have been made by Congress to accommodate the mineral industry no matter how remote the possibilities of a major "find" might be (requests to amend the mineral provisions to permit "temporary" exploration have been rejected in favor of boundary changes); fish and wildlife management representatives have proposed that "management principles" be enacted to "clarify" activities which would be permissible in National Forest wilderness (actually a stalking horse designed to settle what these people see as a fish and wildlife jurisdictional problem. The guidelines could, under one interpretation, permit a game warden to go roaring around in a jeep, checking fishing licenses in a wilderness); ski resort development interests have proposed boundary adjustments to accommodate their proposals, with modest results; the current wilderness water right debate is not only based in an antiwilderness bias, but intends to "clarify" water rights in wilderness by sacrificing them; and so on.

WHAT'S IN THE FUTURE?

So, what does the future hold? Isn't it obvious that as the years pass more and more special interests will be pressing for more and more "exceptions" to accommodate their concerns and objectives? With the exception of the livestock interests (and they were on solid footing, since the Congress merely addressed in greater detail what the provisions of Sec. (4)(d)(4)(2) relative to previously existing livestock grazing mean), none of the other pressure groups has been successful in attempting to amend the Wilderness Act—to date, that is. But as time goes on and, in the event that the current view of wilderness as being only a recreation area should continue unabated, it is a foregone conclusion that enough pressure will be brought to bear on the Congress to enact legislation permitting activities that are not only incompatible today, but illegal. "What we propose will not interfere with existing public uses, Mr. Chairman, but actually will enhance the wilderness experience for thousands of people who cannot use the wilderness now." Even worse, if this kind of wilderness future should come true, a wilderness area, presently the Nation's highest form of land dedication, will become a second-class land form, simply because all sorts of activities will be permitted in wilderness, by law, which are not allowed on public lands outside wilderness, by law.

Only through a well-informed, active, articulate citizenry speaking out in defense of wilderness (untrammeled wilderness, not a recreation area alone) will this future be forgone.

AUTHOR

Harry Crandell
Former Staff Director
House Public Lands Subcommittee
Washington, DC

PERSPECTIVES ON THE HISTORY OF WILDERNESS RESEARCH

Robert C. Lucas

ABSTRACT

Wilderness management-oriented research was almost nonexistent before 1960. About then, recognition of the need for research knowledge to support management and protection of wilderness resulted in studies by Federal, private, and university scientists. Early research was exploratory, largely descriptive, and somewhat naive, but it was an exciting period. By the late 1960's, research efforts matured, and became more theoretical and interdisciplinary. The size of the wilderness research effort grew through about 1978 and has since declined. Early research stressed physical-biological studies of recreation impacts, but the emphasis quickly shifted to visitor studies. Carrying capacity was a major focus. The limits of acceptable change system was developed to deal with the carrying capacity issue. To maximize the contribution of a smaller research effort to protection of the large wilderness system, five recommendations are made.

INTRODUCTION

I have been deeply involved in wilderness research since the late 1950's, and I think that gives me the privilege of presenting a somewhat personal, impressionistic view of the history of wilderness research. I hope this will help us all see where we have come from and be of some value to us in dealing with future challenges.

I will cover three main topics: first, the chronology of wilderness management research, including general trends and research institutional developments; second, trends in the size of the research effort; third, major research themes or topics studied so far. In other words, we will cover the "when," the "how much," and the "what." It is not my intention to present a thorough literature review, to discuss specific results of research, or to list all the persons who have contributed. The nine state-of-the-art review papers at this conference do that much better and in detail. This paper may help set the stage for those reviews, which describe what we have learned and what important questions need answers. I will also briefly review the application of research to wilderness management.

Wilderness research is of two different types—"in wilderness" and "about wilderness." The first, "in wilderness" research, uses wilderness as a setting or laboratory for a variety of research, most of it in the biological and earth sciences. It is not directly focused on wilderness management issues. Most of it can be described as relatively basic research, and can be traced back at least as far as Lewis and Clark and Audubon. John Muir did some of this type of research on glaciation in the Sierra Nevada range. Preserving opportunities for this type of research is one of the important values of wilderness and one of the explicit purposes listed in the Wilderness Act (Public Law 88—577).

The second type of research, "about wilderness," is focused on wilderness management issues, and is relatively applied. It seeks to provide managers with improved knowledge for making effective decisions to protect and preserve the wilderness character of areas in the National Wilderness Preservation System, as they are required to do by the Wilderness Act. Such research also seems related to one purpose of wilderness areas listed in the Act, "the gathering and dissemination of information regarding their use and enjoyment as wilderness." This research deals with topics such as wilderness fire management, control of visitor impacts, wilderness recreation experiences, and visitor management.

This paper will concentrate on the management-oriented, "about wilderness," research. There are borderline cases. The distinction between the two types of research is not always clear, and more of the "in wilderness" research could contribute to management if researchers would highlight management implications of their studies when appropriate. I will aim to err on the inclusive side. Some research conducted outside wilderness, and some done outside the United States, is relevant to management of wilderness and examples will be discussed without pretending to be exhaustive. "Wilderness" will be used in a rather broad, generic sense, not limited strictly to American wilderness classified under the Wilderness Act, although that is the primary focus.

PRE-WILDERNESS ACT BEGINNINGS

Formal wilderness designations did not exist before 1924 when the Gila Wilderness was established by the Forest Service. There have been national parks since 1872 when Yellowstone was designated, but without any specific wilderness direction (Nash 1978). Wilderness preservation in a national park was first mentioned in the act establishing Everglades National Park in 1934. There seems to have been no research and almost no recognition of the need for research to support wilderness management at first. In fact, except for developing and maintaining trail systems, usually more for administration and fire protection than visitor use, there was little management of wilderness.

Bob Marshall, the prime mover behind development of the National Forest wilderness program in the 1930's, was one of the first to recognize that establishing wilderness was not the only issue; management also was necessary. He commented on overused campsites and the need for visitor education in what we would now call minimum impact camping in 1933 (Nash 1978). In 1937, Marshall requested a University of California professor (who was also president of the Sierra Club) to form a committee of scientists to advise the Forest Service on wilderness management, which might have served a purpose similar to research. Another of the early recognitions of issues needing study was by Lowell Sumner of the National Park Service who expressed concern about the impacts of recreational use in 1936 and raised the question of recreational carrying capacity in 1942 (Nash 1978).

There were only a few scattered wilderness research studies before 1960. George Wright and his colleagues in the National Park Service began wildlife research in the late 1920's, and a fauna series was published. Wright and others (1933) dealt with general wildlife relationships in national parks. Others covered individual or related species, for example, Adolph Murie's "The Wolves of Mount McKinley" (1944). Outside wilderness, but of some relevance, was research on the effects of visitor trampling on vegetation. Probably the first was work by H. L. Meinicke in the redwoods in 1928. In the 1930's, trampling studies were conducted in Great Britain by Bates (1935), among others. A 1954 Ph.D. dissertation by James Gilligan analyzed the evolution of Forest Service wilderness policy in detail, and may even have contributed to introduction of the first wilderness bill in 1956.

In the late 1950's, interest in outdoor recreation, and recreation research in general, grew rapidly. Recreation use was growing fast, even explosively in the view of many. Developed recreation facilities, many of which had been built in the 1930's by the Civilian Conservation Corps, were aging and deteriorating. Because of these conditions, the National Park Service launched "Mission 66" in 1956, a 10-year capital investment program to renovate, replace, and expand buildings, campgrounds, and other facilities. The Forest Service followed suit with the similar "Operation Outdoors" the next year.

Both of these major recreation investment programs were launched with no recreation research knowledge base at all. Resource inventories and visitor desires both were handled on a best-guess basis. Perhaps because some policymakers were uneasy about the knowledge gap, the Forest Service commissioned Samuel Dana, Dean Emeritus of the University of Michigan School of Natural Resources, to prepare a problem analysis for research in forest recreation (Dana 1957). This was the result of a recommendation by a U.S. Department of Agriculture Forest Research Advisory Committee, on which Dana also served, that research on forest recreation be stressed. Dana was not a recreation research specialist; nobody was then. However, he wrote a perceptive report. Some of his terminology differs from current jargon, but his analysis is not badly dated even now.

About the same time, Marion Clawson of Resources for the Future, one of the pioneers of recreation research, published "Statistics on Outdoor Recreation" (Clawson 1958). This publication brought together scattered data, primarily on recreational use, for State and Federal lands for the first time. Increasing use was documented, and this captured the interest of a number of people. Clawson also published his influential travel-cost method for measuring recreation demand and value (1959). This and a number of popular articles by such a respected scientist helped build support for research on outdoor recreation.

Also in the 1950's, the very first studies of wilderness visitors and their motives and opinions were done in Minnesota's Boundary Waters Canoe Area by University of Minnesota sociologists (Stone and Taves 1956).

The Sierra Club's Sixth Biennial Wilderness Conference in 1959 addressed "The Meaning of Wilderness to Science" (Brower 1960). As the title suggests, many of the papers dealt with the value of wilderness as a research laboratory, a point made by Aldo Leopold in 1941, but there was recognition in several papers of the need for ecological research to help deal with growing problems of recreational use pressures. Research on visitors was mentioned only briefly in the conferees' discussion relating to one paper.

In 1958, the Outdoor Recreation Resources Review Commission (ORRRC) was established by Congress. This was a major program and reflected the growing public interest in outdoor recreation and the need for an information base for informed decisions. The commission's main summary report in 1962 was accompanied by 27 special study volumes—about 1 foot on the bookshelf. The stimulating effect on interest in outdoor recreation and research produced by this mass of data and analysis at the time is hard to imagine now. There was so little previous scientific literature that these 27 volumes increased available information at least severalfold.

ORRRC Report No. 3 (ORRRC 1962) focused on wilderness. It was prepared by the University of California Berkeley Wildland Research Center, directed by James Gilligan, author of the wilderness policy dissertation discussed before. One of the longer reports, it included historical and policy analysis and data from visitor surveys in three wilderness-type areas. Again, it loomed large in the near vacuum that existed at that time.

THE ACT AND NEW RESEARCH PROGRAMS

Various wilderness bills, 65 in all, were debated in Congress from 1956 to 1964, when the Wilderness Act finally passed. ORRRC Report No. 3, the wilderness volume, recommended passage of a wilderness act. I do not know if that recommendation is related to the odd fact that the wilderness volume alone among the 27 special study reports had to be printed with contributed private funds.

The Wilderness Act does not refer to research explicitly, although the reference previously cited to "gathering and dissemination of information regarding their use and enjoyment as wilderness" can be read as implying research. On the other hand, it probably could be read as implying preparation of brochures on how to visit a wilderness. I have not found anything that clarifies the intent of Congress. Scientific, educational, and historical use are among the authorized uses of wilderness. The first two, at least, are consistent with research. (The meaning of "historical use" is unclear to me, but it could include historical research, as well as viewing historic sites.) I could not find anything in the legislative history that refers to research to support management, although there is testimony about the value of wilderness as a research laboratory—the type of research I have dubbed "in wilderness." Clearly, however, if managers are to meet the challenge of the Wilderness Act to administer wilderness for "use and enjoyment of the American people," to "leave them unimpaired for future use and enjoyment as wilderness," "provide for the protection of these areas," and "the preservation of their wilderness character" some support from research appears to be implied.

In 1959-60, while the Wilderness Act was about halfway through its debate, the Forest Service began its recreation research program (Camp 1984). This was the first tangible recognition of the need for a continuing research program oriented to recreation management issues.

None of the research units at different locations in eight forest experiment stations had wilderness management specifically as a mission at this time, although this was a major part of the early research program at the Pacific Northwest Forest and Range Experiment Station in Portland, OR, where the first research unit was entitled "Wilderness Dynamics." The first wilderness use measurement research (Wenger 1964), and some visitor survey research (Burch and Wenger 1967) were done by this unit. Several other units did some research on wilderness problems in the early years: the North Central Forest Experiment Station (then called Lake States) began with research on use/user characteristics as related to carrying capacity in the Boundary Waters Canoe Area (Lucas 1964), and followed up with fire history (Heinselman 1973) and ecosystem classification studies (Ohmann 1971). The carrying capacity concept presented by Alan Wagar (1964) of the Intermountain Forest and Range Experiment Station was not limited to wilderness but was particularly applicable there. The Northeastern Station began studies of vegetation impacts from heavy use (Ketchledge and Leonard 1970) and visitor attitudes about heavy use in backcountry (Echelberger and others 1974). Thus, wilderness research by the Forest Service began before passage of the Wilderness Act.

The Forest Service also began outdoor recreation cooperative units at five universities in the early 1960's (Camp 1984). These usually consisted of one Forest Service scientist placed in a natural resource or forestry school to stimulate interest (especially by faculty and graduate students), to provide professional leadership in outdoor recreation, and to help train future outdoor recreation managers. The units were modeled somewhat after the Fish and Wildlife Service's cooperative research units. Financial support for university research projects was channeled through these recreation co-op units, some of it wilderness related. Most of the Forest Service scientists did some teaching and student advising. The intent was to fill a near vacuum of recreation expertise in natural resource faculties and to accelerate development of such skills. The Forest Service also foresaw a need for a large number of employees with professional training in outdoor recreation that they felt would not be met without a special program.

At this time, the National Park Service research program was primarily conducted by scientists assigned to individual parks. Most of it seems to have been quite applied, serving largely as staff work for the park line officers. Unfortunately, much was unpublished, and other scientists were seldom able to build on the work. A large part was wildlife research for management decisions and information for interpretation. Some was natural history, geological, historical, or prehistorical research.

This period of the early 1960's was a time of excitement associated with new beginnings, idealism, and a certain amount of naiveté. Outdoor recreation grew in recognition as an important program, although there was still some insecurity about the respectability of studying a noncommodity output that was not generally viewed as a necessity of life. Researchers had high hopes of providing solid answers to basic, usually rather simple questions, such as "what do people want?", "how much use is too much?", and so on. It really was great fun!

Many disciplines were involved: social sciences, biological sciences, and forestry, which was primarily biological in orientation within a professional management program. There was a considerable amount of trial and error, not a great deal of coordination, and some scattering of efforts that was probably inevitable in the newness of the effort, and perhaps necessary to start the development of concepts and structure for research. At this early stage, there were no journals focused on outdoor recreation research. This contributed to the limited coordination and scattering of efforts, especially with so many disciplines involved.

By the late 1960's or early 1970's, the early research efforts evolved and matured into what seems to me to have been a stronger, more coordinated and coherent program. The simplicity and naiveté were replaced with more recognition of the complexity of the issues and the elusiveness of simple, easy answers, magic numbers, and the like. Recreation managers were also becoming more professional and knowledgeable. This resulted in more productive interaction between managers and researchers.

The National Park Service began to play a more prominent role in wilderness research in this period. The first permanent, full-time research sociologist, Neil Cheek, joined the Park Service in 1968. In 1970 the first of the cooperative park studies units (CPSU) was established at the University of Washington (Agee and others 1982-1983), led by Don Field. The number of these research units has grown to 35, and about 15 have a resident Park Service scientist. These are located in all parts of the country, but are most common in the West.

The CPSU's have similarities to the Forest Service cooperative units beyond the name, but major differences as well. The Forest Service units were meant to serve the temporary needs of the universities, and when those needs were met by the late 1960's, as the universities developed their own expertise, the units were phased out. In contrast, the Park Service CPSU's primary function is to meet the research needs of the national parks

(Agee and others 1982-1983). Teaching and extension are also outputs from the CPSU's, but research to meet the needs of individual national parks and general problems of groups of parks is uppermost. Research is done not only by National Park Service scientists but also cooperatively by university scientists with appropriate skills and interests. Some has involved cooperation with Forest Service researchers, and this has led to research on regional recreation systems, cutting across agency boundaries, in Alaska, for example (Clark and others 1982). Some of this research relates directly to wilderness; for example, a series of visitor studies in Alaska (Womble and others 1978). Systems for handling backcountry permit data were also developed (Field and others 1977).

In 1967 the first and only research unit with wilderness management as its sole mission was established by the Forest Service in Missoula, MT, as part of the research program of the Intermountain Forest and Range Experiment Station. It was staffed by George Stankey and I, and later, for a time, by Randy Washburne, David Cole, and Margaret Petersen. The major focus has been visitor management research, including descriptive surveys, social carrying capacity studies, use measurement methods, redistribution of use through information, use and encounter simulation models, and management systems, such as the Recreation Opportunity Spectrum and Limits of Acceptable Change. Ecological impact research was begun in 1978 when David Cole joined the unit on a temporary appointment and has continued through cooperative research after his appointment ended. This research program is reviewed in Lucas and others (1985).

There was also some wilderness research by other Forest Service recreation research units, as part of their research program missions, although none was directly focused on wilderness. At the Rocky Mountain Station, Bev Driver's work on experience preferences or motivations, some of it in cooperation with Perry Brown and others at Colorado State University, was applied to wilderness visitors in Colorado and Wyoming (Brown and Haas 1980), and to an integrated management planning pilot project for the Maroon Bells-Snowmass Wilderness in Colorado. At the Northeastern Forest Experiment Station, Ray Leonard studied recreational impacts on soils (Leonard and Plumley 1979a) and capacity concepts (Leonard 1976), and Skip Echelberger and George Moeller did wilderness visitor surveys (Echelberger and Moeller 1977). At the North Central Station, Dave Lime and cooperator George Peterson did further research in the Boundary Waters Canoe Area on use patterns (Lime 1972), visitor expectations and preferences (Peterson 1974), use estimation (Lime and Lorence 1974), and simulation models. Dorothy Anderson studied displacement-succession (Anderson 1980). George James at the Southeastern Station included wilderness in a continuing program of recreational use measurement research (James 1971). At the Pacific Northwest Station, John Hendee and Roger Clark did wilderness-related research, including a study of visitor characteristics and attitudes in three Washington and Oregon wildernesses (Hendee and others 1968), littering behavior in wilderness (Muth and Clark 1978), and surveys of southeast Alaskan recreationists (Clark and others 1982).

The Park Service wilderness-related research concentrated on natural sciences—botany, zoology, ecology—while Forest Service research focused on recreation use (Butler and Roberts, this proceedings).

Resources for the Future continued to be active in recreation and wilderness research, particularly opportunity costs of development of natural areas (Krutilla and Cicchetti 1972) and wilderness use simulation (Shechter and Lucas 1978).

Conservation organizations also contributed to early research. The Appalachian Mountain Club established a research department and began study of social and ecological problems (for example, Taylor and Mackoy 1980). The Sierra Club sponsored a group of studies on recreation impacts in the Sierra Nevadas in the early 1970's (Stanley and others 1979).

Strong university research involvement developed at a number of places. At risk of offending someone by omission, wilderness-related research comes to mind at such universities as Colorado State, Washington, Michigan, Virginia Polytechnic, Utah State, Minnesota, Vermont, Oregon State, Texas A&M, Idaho, Montana, and Montana State. Most of this research activity centered around forestry and natural resource schools, but it also involved park and recreation departments, and geography, psychology, sociology, economics, botany, and zoology. A wide variety of topics related to wilderness have been studied. Publications have appeared in many different journals and other outlets, but it is my impression that social science or visitor studies have predominated strongly, with fire and visitor impacts well behind.

The first recreation research journals appeared. None focused on wilderness, but they included wilderness research. First was the *Journal of Leisure Research* in 1969, then *Leisure Sciences* in 1977. Several new journals with a biological, environmental, conservation emphasis also appeared in this period, although none of them provided as much of a forum for wilderness-related research as the two essentially social science journals. In 1981, *Pacific Park Science*, published by the National Park Service, went national and became *Park Science*. At present, its focus is on national park management and most contributors are National Park Service employees. This leaves a gap; there is no journal aimed at wilderness managers. The *Journal of Forestry*, particularly, and the *Journal of Soil and Water Conservation* have been the primary outlets for articles written for wilderness managers.

SIZE OF RESEARCH EFFORT

The wilderness-related research effort began from scratch about 1960. I will use Forest Service recreation research as a handy example because it was the first separate, discrete program; it has a readily identifiable budget; and has involved a substantial amount of research on wilderness topics over the years. Growth from 1960 through the middle 1970's was rapid and fairly steady, increasing about ninefold in budgets (fig. 1) and with a smaller but substantial growth in staff. Then, in 1978, the recreation research program doubled, and urban forestry research was initiated and added to the recreation research program. The budget peaked in 1979 at about $3.3 million. After this one brief, euphoric burst of growth, it has been all downhill, although irregularly, declining about 40 percent from 1979 to 1985. Staffs have declined only slightly, and, as a result, operating budgets for field research and cooperative studies with university scientists have plummeted.

The Forest Service wilderness management research unit began in 1967 in Missoula, MT. The changes in its size have followed a path similar to that for recreation research in general—fairly steady growth through 1977, then nearly a doubling in 1978 to a high of $310,000, followed by a decline of about 45 percent (fig. 1). Staff grew from two to five and now is back down to two. All budget figures are in nominal dollars. Adjustments for inflation diminish earlier growth and accentuate later declines. Using constant 1982 dollars (GNP price deflator), the budget grew 61 percent from 1968 to 1977, grew 64 percent from 1977 to 1978, and declined 57 percent from 1978 to 1985.

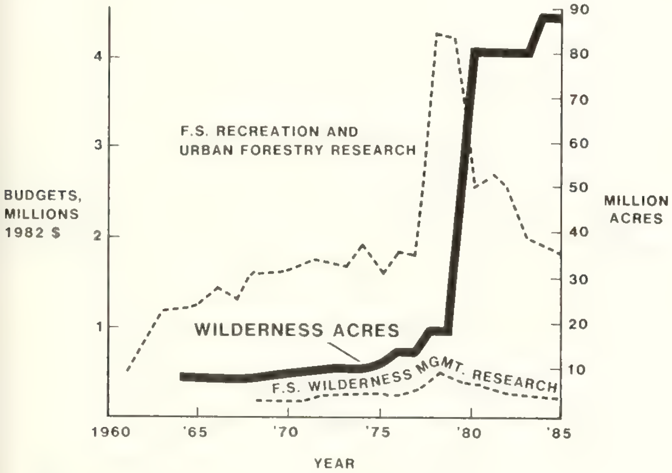


Figure 1.—Trends in size of the National Wilderness Preservation System and budgets for related Forest Service research.

The National Park Service research program in the parks and at the cooperative park studies units grew in the 1970's and has been relatively stable since then. The Cooperative Park Studies Units contract for over $1 million of research per year, on the average (Agee and others 1982-1983).

Research budgets for the national parks apparently have fared better in recent years than those in the Forest Service. One might speculate that this reflects the close link to park management needs contrasted to the more independent role played by Forest Service research.

University wilderness research is too widespread and diverse to be tallied and quantified. However, it probably followed somewhat the same pattern of growth until the late 1970's and decline since then, less extremely than Forest Service wilderness research. Numbers of professors involved in wilderness research, amount of faculty time, and numbers of graduate students also first grew, then leveled off, and declined. Contract and grant sources and funds for cooperative research that support much of the university wilderness research all grew and now have been declining for 5 years or more.

It seems only reasonable to presume that the production of new knowledge, solution of important problems, and technology transfer from researchers to managers reflect in general the resources devoted to wilderness-related research, and therefore these also rose and then declined.

In sharp contrast to the recent decline in wilderness research, the size of the wilderness system has grown greatly, from 9 million acres in 1964 when the Wilderness Act passed, to over 88 million acres early in 1985 (fig. 1). Assuming total expenditures by all agencies and universities for wilderness-related research are five times the budget of the Forest Service wilderness management research unit, about $0.09 (1982 dollars) was spent per acre of wilderness in the late 1960's. In 1985, about $0.01 per acre of wilderness is being invested in research for wilderness management and protection. By my estimate, commercial timberland research amounts to $0.50 or more per acre. I do not believe the relative values at stake, the difficulties of management, or the adequacy of existing knowledge for timberland management compared to wilderness protection justify this wide disparity. Managing wilderness to do an acceptable job of protecting it and producing benefits for society will require a larger research effort.

MAJOR RESEARCH THEMES

I will divide the discussion of research themes into two periods, the early period from about 1960 through the early 1970's, and the late period from the early 1970's to 1985. (Because the lag between research and publication varies widely, some of the studies I call "early" have publication dates past the early 1970's.)

The Early Period

In general, the earliest outdoor recreation research was exploratory. There was considerable uncertainty about what the problems really were and what research approaches were appropriate. Concepts and theories were absent from most of the studies, implicit in some, and explicit and formal in only a few.

As was appropriate at this early stage, much of the research was largely descriptive, providing reliable information about wilderness recreation characteristics, patterns, and effects. However, it is unfair to describe most of this research as "mere description" or "purely descriptive." From the first, many of the studies went beyond description to analyze relationships and offer explanations. Basic descriptions also were an essential foundation, I think, to the more specialized, sophisticated research that followed.

Physical and Biological Research.—Biophysical research on ecological processes and visitor impacts began early, and was stressed more than visitor research initially. Most of the first impact research was conducted at developed recreation sites, mainly campgrounds and picnic areas, rather than wilderness (for example, LaPage 1962). This served to develop techniques and concepts that were applied later to wilderness settings.

Soon research in backcountry dispersed recreation settings, including wilderness, began to address wilderness management topics more directly. Much of it dealt with impacts, mainly to vegetation, and with the role of natural fire in wilderness ecosystems.

Early impact research made limited use of range management science for principles and approaches to studying vegetative disturbance. There was a little research on the effects of grazing by recreational stock (Sharsmith 1959), but campsite conditions were the main focus of impact research, with trail conditions receiving somewhat less attention. Most studies were mainly attempts to document impacts in a systematic, accurate way (see the annotations of studies in Cole and Schreiner 1981). A few attempted to relate impacts to site conditions such as forest versus meadow and degree of closure of forest canopy (Schreiner and Moorhead 1976), and even fewer dealt with amount of use (Frissell and Duncan 1965). Most of the campsite studies were based on measurement of conditions on already existing sites. One exception was a study of newly created campsites in the Boundary Waters Canoe Area (Merriam and Smith 1974). Vegetation impacts were the main concern, with lesser attention to soil compaction. There were also several studies that applied experimental trampling to vegetation (Bell and Bliss 1973). Research on trail erosion almost always dealt with conditions on existing trails. One of the earliest trail erosion studies was conducted in the Adirondack Mountains of New York by Ketchledge and Leonard (1970). A review of research on the ecological effects of outdoor recreation by Speight (1973) summarizes much of the early period impact research. Almost 200 publications were reviewed from Britain, western Europe, and North America.

Many ecological and impact topics received very little attention in the early period. Impacts of recreational use on water quality were only rarely studied (Barton 1969). Recreational impacts on wildlife, other than the direct effects of hunting and fishing, were almost unstudied. There was a large amount of general wildlife research, some of it conducted in wilderness. This research dealt with issues such as home ranges, movement, feeding behavior, reproduction rates, and so on, much of which is relevant to perpetuation of natural populations. This research contributes at least generally to wilderness management decisions. Examples include research on moose-wolf relationships on Isle Royale (Mech 1966); mountain lions in the Idaho Primitive Area (Hornocker 1969); and grizzly bears in Yellowstone National Park (Craighead and others 1974). Studies of recovery of vegetation from the effects of recreational use were largely missing during this early stage, as was research on air quality.

Some research on plant succession was done in the early period. Very early research examined succession in mountain meadows in California (Sharsmith 1959). Most of this early research focused on plant succession in relation to natural fire. Fire history studies were fairly common near the end of the early period, including Sequoia-Kings Canyon National Park in California (Kilgore 1973); the Selway-Bitterroot Wilderness in Idaho (Habeck 1972); Glacier National Park, MT (Habeck 1968); Yellowstone National Park, WY (Houston 1973); Everglades National Park, FL (Robertson 1962); and the Boundary Waters Canoe Area, MN (Heinselman 1973). Research on fire's natural role resulted in the rapid evolution of agency policy toward restoration of natural fire in wilderness. To date, this probably is the most conspicuous example of the application of research results to wilderness management.

Physical-biological research on wilderness impacts and ecological processes in the early period was concentrated in the mountain landscapes of the West, including western Canada, and in northern Minnesota. There were a few studies in New England, most by Ray Leonard, and, later, in the Southeast. (Other research was conducted overseas, in Great Britain, western Europe, and Japan.) There was almost no research in deserts, grasslands, or river corridors at this time.

Almost all studies were one-time descriptions; longer term trend studies were very scarce.

Social Research.—Social research on visitor use patterns, attitudes, activities, and demographic characteristics began in the early period, with attitudes receiving particular emphasis. Visitor surveys were fairly common, although the scientists carrying them out had to contend with difficult sampling and data collection problems (Lucas and Oltman 1971): users were widely dispersed, relatively few, and highly variable in number, all resulting in high sampling costs, small samples, and large variances. For example, the wilderness report by ORRRC (1962) described their attempts to survey visitors to seven wildernesses, but they obtained samples large enough to analyze in only three areas. The potential for interference with visitors' wilderness experiences also limited some approaches to collecting information.

Most of the wilderness visitor surveys were more than purely descriptive "census reports." Data were analyzed in terms of types of use and characteristics of visitors, as well as attitudes, such as Hendee's "wilderness purism" scale (Hendee and others 1968). The surveys helped clarify the nature of wilderness recreation, and indicated the limited truth of a number of common misconceptions about wilderness use and users (Stankey 1971).

Early visitor surveys provided a general picture of wilderness visitors (Lucas 1964; Hendee and others 1968; Murray 1974). Visitor characteristics tended to be similar in many wildernesses, but activities and behavior were more variable and site specific. The most distinguishing characteristic of wilderness visitors in every study was high education levels.

Use measurement methods received considerable research emphasis during this early time. Much of this research was done by Jim James from the Forest Service Southeastern Forest Experiment Station (James 1971). Reasonably accurate, cost-effective, practical techniques for measuring wilderness recreational use were needed to provide data that are basic both to skilled professional management and to many types of research. Most of the research dealt with systems for calculating use estimates based on trail register data or various types of traffic counters. Computerized systems for summarizing wilderness permit information were developed (Elsner 1972; Frayer and Butts 1974; Field and others 1977).

The wilderness use measurement research was a part of a more general effort to develop recreation use measurement systems, including systems for developed sites of various kinds. Usable methods were developed for campgrounds in particular, and incorporated into widely used handbooks. This did not happen for wilderness use estimation, which was more difficult and expensive, for much the same reasons mentioned in connection with visitor surveys. The problem was potentially solvable to a greater degree than many other wilderness research topics, but it did not receive enough effort long enough to finish the job and produce completed technology for transfer to managers. James retired and research to develop an integrated wilderness use measurement program was dropped shortly after.

Carrying capacity was one of the major themes of research in the early period. Research focused on concepts or approaches to carrying capacity (Wagar 1964; Lime and Stankey 1971; Frissell and Stankey 1972). Very early physical-biological capacity was emphasized, but social carrying capacity quickly replaced it as the main thrust of research, with stress on investigations of the solitude dimension of wilderness experiences and visitor standards for solitude (Lucas 1964; Stankey 1973). The important role of the human dimensions of wilderness management is another research output adopted by managers, gradually but widely. This concept is so generally accepted now that its origin in research is no longer recognized.

The social carrying capacity studies laid down many principles that later research confirmed. Results indicated that satisfactions depend on more than use level, particularly on type, frequency, and location of encounters. It was recognized early that capacity had to be related to management objectives.

There was some early emphasis on economic research; most focused on outdoor recreation in general, but some related to wilderness. Much of this early economic research is discussed in Clawson and Knetsch (1966). Part was concerned with general economic values. Another part dealt with demand, travel cost models to estimate demand for and value of individual areas, gravity models, and intervening opportunity analyses to attempt to explain and predict use of specific areas, and economic impacts on local regions.

There were other topics addressed by a study or two; for example, Nash's classic work on the intellectual history of wilderness, first in *Forest History* (1963), then in a major book (1982—with the first edition published in 1967), or Hughes' (1965) study of wilderness land allocation.

Early social research, like physical-biological research, also was concentrated in the West and the Boundary Waters Canoe Area-Quetico Park region. There was a little in New England and eastern Canada. There was considerable social recreation research in Canada, some of it wilderness related; for example, see the wilderness bibliography by Herrick (1974).

Little or no early research was conducted on wilderness visitor education/information programs (although there was a little in nonwilderness situations). No general population studies were related to wilderness; all the studies were based on samples of current on-site visitors. There were no trend studies; all of the visitor research was based on one-time surveys.

The Late Period

After the early 1970's, wilderness studies became more narrowly focused and more scientifically rigorous. There was more conscious effort to develop theories, concepts, and models. Samples were better designed and multivariate statistics were used more in analysis.

As many different disciplines were involved as before, but there was at least a little more communication and collaboration and less "go it alone" research. Communication was enhanced by the new journals (*Journal of Leisure Research, Leisure Sciences, Environment and Behavior, Environmental Conservation, Journal of Environmental Education, Park Science,* and so on), and more review bibliographies. Conferences and symposia focused on wilderness also furthered collaboration. Conferences included wilderness management meetings in Seattle in 1973 and at the University of Idaho in 1983, a wildlands recreation impact conference in Seattle in 1978, conferences on wilderness in the East held in Knoxville in 1980 and Nacodoches, TX, in 1985, a wilderness fire symposium in Missoula in 1983, and World Wilderness Congresses in 1977, 1980, and 1984 in South Africa, Australia, and Scotland. Other conferences were not focused just on wilderness but included many wilderness concerns; for example, the wildland recreation conference in Banff National Park (Canada) in 1978, river recreation conferences in Minneapolis in 1977 and Baton Rouge in 1984, the trends symposia in Durham, NH, in 1980 and Myrtle Beach, SC, in 1985, and conferences on scientific research in the national parks held in New Orleans in 1976 and San Francisco in 1979.

Biophysical research on impacts and ecological processes continued, but the balance between visitor studies and biophysical research shifted in the early period toward visitor studies. The view that visitor research should receive higher priority was widely adopted. Reasons included the belief that less was known about visitors in comparison to biophysical processes, change affecting visitors was more rapid, potential consequences were more serious, and that wilderness management is largely people management. All these were probably true at the time, but the pendulum, in my view (and I am a social scientist), swung too far away from research on interactions between visitors and soils, vegetation, water, and wildlife, particularly, and has stayed away too long. Except for natural fire research, there were too few biophysical scientists and too little wilderness-related research in most of this period to achieve a "critical mass." Unlike social researchers, there were few biophysical scientists deeply involved in wilderness research and few careers devoted to it.

Physical and Biological Research.—Campsite impacts received major emphasis in biophysical research in this period, as they did earlier. Research revealed the complexity of the impact process and its management. The relatively minor role of total amount of use in determining impacts became clearer (Marion and Merriam 1985; Cole 1982). Campsite condition rating systems were developed. One by Frissell (1978) was widely used, as was the monitoring approach developed by Cole (1983a). Sometimes the two systems were combined, and occasionally integrated into the Code-a-site campsite inventory data management system (Hendee and others 1976).

There was considerable research on trail conditions. It became clear that heavy use was not the main cause of trail deterioration. Location, design, maintenance, and type of use were more important (Helgath 1975, for example). Monitoring techniques for trails were developed (Leonard and Whitney 1977; Cole 1983b). Application of research to trail management has lagged, in large part due to the decline in major trail work as wilderness management budgets have dropped.

Other research dealt with vegetation recovery and rehabilitation of campsites particularly, and trails to a lesser extent. An annotated bibliography by Cole and Schreiner (1981) indicates the scope of this research.

Impacts of recreational use on wildlife, primarily disturbance and indirect effects on habitat rather than hunting or fishing, received some attention in the later period, as documented in an annotated bibliography by Ream (1980), but knowledge gaps for this topic remain severe. There also was a continuation of more general, basic wildlife studies, usually of individual species (such as eagles, grizzly bears, wolves), much of it by National Park Service scientists and cooperators.

Some water quality research was conducted in this period, as is apparent from the studies reviewed by Christensen and others (1979). There also were several studies of human sanitation under wilderness conditions (Leonard and Plumley 1979b; Temple and others 1980, 1982).

Only very recently has there been any research on air quality as it affects wilderness; for example, research on the effect of air pollution on vegetation and water chemistry in progress in the Wind River Range, WY, and current studies of visibility changes as they affect visitors in Grand Canyon and Mesa Verde National Parks. A workshop addressed changes in air quality affecting the Flat Tops Wilderness in Colorado (Fox and others 1982) and Malm (1983) described the basic processes affecting visibility in relation to national parks. Rowe and Chestnut (1983) edited a series of papers on air quality in national parks and wilderness.

Fire research was emphasized in the later period, with accumulating knowledge on fuels, fire behavior, fire histories, and growing managerial experience in applying policies that helped permit fire more nearly to play its natural role in many wildernesses. Knowledge about wilderness fire was summarized in a major conference in Missoula in 1983, documenting major advances. Both the Forest Service and Park Service, as well as university scientists, were active in research on fire in this period.

There was still not much research on basic ecological processes (see the paper by Franklin in these proceedings). The overall knowledge base from impact research and more basic ecological research was still fairly weak and did not provide an adequate foundation for many recommended minimum impact visitor use practices suggested by managers and sometimes incorporated in regulations.

Social Research.—Social research shifted its focus more than biophysical research in the later period and also increased more. Visitor surveys became less common than earlier, and research related to development of use measurement methods diminished, with the problem still not quite solved. Objectives for measuring backcountry use and the advantages and disadvantages of the available technology were summarized by Leonard and others (1980). Social carrying capacity research grew, and intensive questioning of earlier formulations occurred (Graefe and others 1984). Earlier research had shown strong negative evaluations of increasing contact with other parties (Stankey 1973), but some later research showed little or no association of contacts and satisfaction, especially on rivers. A synthesis is emerging, drawing on ideas present, at least implicitly, in the earlier research (Stankey and McCool 1984). This approach takes into account individual variation in visitor motives, recognizes that seeking solitude is one of a number of motives, and views satisfaction as a complex concept, difficult to measure, and influenced positively and negatively by many factors in addition to number of encounters.

The issue behind all research activity concerned with carrying capacity was the question originally phrased as "How much use is too much?" Much carrying capacity research aspired to determine a maximum amount of use, without much success. Application lagged. But the basic question has gradually, over more than 10 years, been redefined and a solution proposed. The redefined question is "What sort of conditions resulting from use are acceptable?" It includes a concern for both biophysical and social conditions—in other words, for both visitor impacts and experiences. The related question of how to manage for capacity also shifted from a narrow focus on limiting or redistributing use to a broader array of management actions affecting visitor behavior as well as numbers and distributions.

The proposed solution is management within limits of acceptable change, or the LAC approach (Stankey and others 1985). With the clear vision of hindsight, LAC now seems so obvious to me, so practical and feasible, that it is hard to comprehend why it took so long for us to grasp it, especially since the basic ideas had been in the literature since the early 1970's (Frissell and Stankey 1972) and even before. Of course, many developments look simple in retrospect, and turning the basic idea into a coherent, sequential management system founded on research knowledge was a complex challenge. The LAC approach integrates social and ecological concerns, which has not been common. LAC may provide a vehicle for further collaboration and integration of social and biological research. Current applications of LAC (Stankey and others 1984) may indicate unforeseen problems and the need for further development, but this system seems to have the potential to become another major example of successful technology transfer.

Related to the concern for managing for carrying capacity, several simulation models of wilderness recreational use were developed in this period. One model relates number of groups entering at various access points to resulting use in travel zones. The numbers of campsites in each zone were compared to simulated use to establish entry point quotas that would not result in use exceeding campsite capacity (Peterson and others 1977). This model was developed for the Boundary Waters Canoe Area Wilderness and applied there. Another model simulates use levels and various types of encounters among visitors for specific locations (Shechter and Lucas 1978). It was applied by managers in California to develop use limits with minimal restriction of use and in Colorado to develop encounter standards and to select sites for use monitoring, and in teaching wilderness management (Manning and Potter 1984).

Benefits and values were studied more in this period, particularly in social-psychological terms. Attitude scales were constructed to measure a wide variety of motives or preferred outcomes, and were applied to many participants in a diverse range of activities in varied settings, including wilderness (for example, Brown and Haas 1980). General study of attitudes about wildlife and wildlife values also had some relevance to wilderness (Kellert 1976).

Economic analysis of values continued. Some of it focused specifically on wilderness (Walsh 1982, for example), some of it dealt with recreation and wildland values in general (Peterson and Randall 1984, for example). Opportunity costs of allocating forest land to wilderness were studied in southwestern Montana, where they were low, and western Oregon, where they were high (Campbell and Countryman 1981).

Some research explored means of changing problem behaviors, particularly littering, by using incentives or appeals, and part of this research has been applied to wilderness visitors (Muth and Clark 1978). Some related research tested the effect of various types of information on wilderness visitors' choices of when and where to visit (Lime and Lucas 1977; Lucas 1981; Krumpe and Brown 1982) and where to camp (Roggenbuck and Berrier 1982; Echelberger and others 1983). Information campaigns designed to cause wilderness visitors to adopt other minimum impact practices have scarcely been studied, however, despite the large amount of effort managers are putting into minimum impact education.

Trends have received little research attention (Lucas 1985 reviews the few trend studies done, and the National Park Service CPSU scientists are repeating some of the Alaska visitor surveys). Projections have been studied even less (Jungst and Countryman 1982).

RESEARCH APPLICATIONS

Wilderness managers have benefited substantially from a productive relationship with research. Some contributions are distinct and readily identified, others are more general concepts that have been widely adopted and whose roots in research are no longer obvious.

Among the more distinct research outputs are: wilderness fire management programs; campsite inventory systems; trail register systems; computerized use-data summary programs; general approaches to use measurement; equitable use-rationing systems; the basis for party size limits; simulation models used to ration use; advantages of education approaches (high visitor education levels and commitment to wilderness); use of information to redistribute use; the limits of acceptable change system; recognition of the ineffectiveness of campsite closure as a rehabilitation technique; identifying location, design, and maintenance of trails, rather than amount of use, as the keys to controlling deterioration; and many site-specific results.

Some of the broader, more general research concepts that now are part of the overall approach to wilderness management are that experiences are the major output of management, that diversity in experiences is essential, that visitor conflict is an important problem, that visitor displacement can occur, that wilderness management is largely visitor management, that objectives are critical to wilderness management, that wilderness use is very unevenly distributed geographically and over time, that nonregulatory management fits visitors' goals well, much of the concept of minimum impact use, recognition that carrying capacity involves social as well as ecological factors, the fact that most resource impacts result from light use, and the role of many factors besides amount of use in producing impacts.

Research contributions to wilderness management are presented in more depth in the book *Wilderness Management* (Hendee and others 1978).

The professional skill of wilderness managers has matured and grown over the last 20 years, with researchers' work contributing to this process. Managers' attitudes have also changed, for the better I feel. I recall early management meetings at which a major topic of discussion was the validity of wilderness as a land classification and expressions of frustration that "business as usual" could not prevail in wilderness. It has been a long time since I have heard those tunes. Acceptance of wilderness, commitment to its preservation, and serious concerns about how to manage it effectively are the rule at present wilderness workshops. And the general concepts listed above are widely understood by wilderness managers today.

CONCLUSIONS

The wilderness system is large and growing (fig. 1). There are many new wilderness managers as a result of additions to the system. In 1964, only 55 National Forests had any wilderness; now 128 do. Eighty-two percent of all National Forests have to face the challenge of managing wilderness. More national park, wildlife refuge, and BLM managers have wilderness responsibilities, and almost surely more will in the future. Many of the people now managing wilderness have no previous experience in this demanding type of management, and no training. Most wildernesses are totally unstudied, and some whole types of wilderness and kinds of wilderness users are virtually unstudied; for example, desert wilderness, or snow-season visitors.

A strong knowledge base is essential to protect and manage the over 88 million acres of established wilderness. Society has a large investment in the wilderness system, and has forgone many other uses of the land. Will skilled professional management enable society to obtain a return, in the form of preservation of wilderness conditions and opportunities for high-quality wilderness experiences, that will make this large investment worthwhile? Can management provide adequate returns to society with the present level of knowledge? The research whose history has been reviewed can help. We have come a long way in research-based knowledge for wilderness management since the early 1960's. But there is a great deal left to learn. Furthermore, the management problems themselves evolve and change. Results of three surveys of wilderness managers over a 5-year period hint at such changes (Godin and Leonard 1979; Bury and Fish 1980; Washburne and Cole 1983).

Limited management budgets make it more critical that management be highly effective and sharply focused on important problems. This seems to require improved knowledge of wilderness resources, natural processes, visitor and external impacts, visitor desires and behavior, and the effect of management actions.

However, less wilderness research is being done now. Support has diminished for 5 or 6 years. Agency research and support for university and consultant research are down. New sources of support need to be developed. The Wilderness Research Foundation, which will be introduced at this conference today, may help fill this need. I hope so, but other funding sources will be essential.

There are barriers to wilderness research besides shrinking budgets. Most are not new, but some are becoming more serious. The Federal Paperwork Reduction Act, administered by the Office of Management and Budget, deals with the important problem of government reporting requirements that constitute a heavy burden for businesses and local governments. All collection of information by Federal Government employees or by anyone who is federally supported must be reviewed and approved by the Office of Management and Budget. Technical review of questionnaires and research design to assure quality control is certainly desirable. However, the application of lengthy, formal approval procedures to small-scale, voluntary questionnaires used in wilderness visitor studies impedes effective research in response to managers' needs. Planning lead time now exceeds 1 year as a result of requirements for advance listing in annual information collection budgets and the typical drawn-out process of review. Even the term "respondent burden" seems of questionable appropriateness for voluntary questionnaires. Many recent surveys have used mail questionnaires, and 80 to 90 percent rates of return are usual. Visitors are answering questions about something important to them, and most of them welcome the opportunity to express themselves. Seriously hampering research in order to protect people who seldom feel imposed upon seems unfortunate.

Some wildernesses have dropped permit requirements and others have abandoned trail registers. The reasons for these changes are unclear. Shrinking budgets, failure to use permit or register data effectively for management and thus assignment of low priority to collecting the data, and a desire to not obligate visitors unless truly necessary are all partial reasons for this retreat. These may be justified decisions, but they result in the loss of basic data on use and users that can impede both visitor and impact research.

Sometimes agency policies can make basic ecological research more difficult (Franklin, this proceedings) or hamper fire history research (Kilgore, this proceedings). It appears that less research is conducted in National Forest wilderness than in national park backcountry and wilderness (Butler and Roberts, this proceedings).

In this situation, I think there are five things members of the wilderness research community need to do:

1. Select high-priority problems to study. We will have to leave most problems unstudied, but clearly these should be problems of lesser importance.

As I have indicated earlier in the paper, I think wilderness managers will need more research on the impact process in a variety of settings. They need research on the effectiveness of various minimum impact practices in different situations. They need research to guide wilderness fire programs, especially manager-ignited fires. They need to have research finish the job of developing use measurement systems. They need help from research in applying the Limits of Acceptable Change system, and research to plug some remaining gaps (Lucas and Stankey 1985). Research needs to evaluate and develop nonregulatory visitor management techniques, especially education-persuasion. Trends need to be identified, including displacement of visitors by changing conditions. Finally, research needs to better cover the wide range of conditions and uses in the expanded wilderness system now established.

2. Do rigorous, high-quality research, to learn as much as possible from reduced amounts of research.

3. Collaborate and communicate with other researchers, with wilderness managers, and with concerned publics. This can help focus efforts on the most important issues and improve the quality of studies. It can also facilitate application of research to wilderness management. A good example of collaboration between university, Forest Service, and private consulting firm scientists, managers, and the public in the development of the Limits of Acceptable Change system and its application to the Bob Marshall Wilderness is described in this proceedings (McCool and others).

4. Strive for comparability and additivity to achieve a more integrated, cohesive research effort. I think at least one large, unified wilderness research program would facilitate integration, but if this fails to develop, scientists will need to work harder at cooperation. That, of course, is a major goal of this conference. If more studies could use common units of measure, comparable data classifications, and so on, one study could build on another more than has happened in the past. This could also facilitate study of trends.

5. Finally, strive for better days, so research can contribute to the management and preservation of wilderness. There is too much at stake for wilderness research to be neglected.

REFERENCES

Agee, James K.; Field, Donald R.; Starkey, Edward E. Cooperative park studies units: university-based science programs in the National Park Service. Journal of Environmental Education. 14(2): 24-28; 1982-1983.

Anderson, Dorothy H. Long-time Boundary Waters' visitors change use patterns. Naturalist. 31(4): 2-5; 1980.

Barton, Michael A. Water pollution in remote recreational areas. Journal of Soil and Water Conservation. 24(4): 132-134; 1969.

Bates, G. H. The vegetation of footpaths, sidewalks, cart-tracks and gateways. Journal of Ecology. 23(2): 470-487; 1935.

Bell, K. L.; Bliss, L. C. Alpine disturbance studies: Olympic National Park, U.S.A. Biological Conservation. 5: 25-32; 1973.

Brower, David, ed. The meaning of wilderness to science: proceedings, sixth biennial wilderness conference; 1959 March 20-21; San Francisco, CA. San Francisco: Sierra Club; 1960. 130 p.

Brown, Perry J.; Haas, Glenn E. Wilderness recreation experiences: the Rawah case. Journal of Leisure Research. 12(3): 229-241; 1980.

Burch, William R.; Wenger, Wiley D. The social characteristics of participants in three styles of family camping. Research Paper PNW-48. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1967. 30 p.

Bury, Richard L.; Fish, C. Ben. Controlling wilderness recreation: what managers think and do. Journal of Soil and Water Conservation. 35(2): 90-93; 1980.

Camp, Harry W. Recreation research by U.S. Forest Service: a history. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1984. 68 p. [Draft]

Campbell, Gene E.; Countryman, David W. Comparing estimated wilderness costs among national forests. Journal of Forestry. 79(9): 605-607; 1981.

Christensen, Harriet H.; Pacha, Robert E.; Varness, Kevin J.; Lapen, Robert F. Human use in a dispersed recreation area and its effect on water quality. In: Ittner, Ruth; Potter, Dale R.; Agee, James K.; Anschell, Susie, eds. Conference proceedings: recreational impact on wildlands; 1978 October 27-29; Seattle, WA. No. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 107-119.

Clark, Roger N.; Johnson, Darryll R.; Field, Donald R. The Alaska public survey—a comprehensive assessment of recreational values and use patterns and natural resource management. In: Lime, David W., coordinator. Forest and river recreation: research update; selected papers presented at the symposium on leisure research, National Recreation and Park Association; 1981 October 25-27; Minneapolis, MN. Miscellaneous Publication 18. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1982: 115-119.

Clawson, Marion. Statistics on outdoor recreation. Washington, DC: Resources for the Future; 1958. 165 p. [Reprinted as: Clawson, Marion. Part I. The record through 1956. In: Clawson, Marion; Van Doren, Carlton S. Statistics on outdoor recreation. Washington, DC: Resources for the Future; 1984: 1-158.]

Clawson, Marion. Methods of measuring the demand for and value of outdoor recreation. Reprint Number 10. Washington, DC: Resources for the Future; 1959. 36 p.

Clawson, Marion; Knetsch, Jack L. Economics of outdoor recreation. Baltimore, MD: Johns Hopkins University Press; 1966. 328 p.

Cole, David N. Wilderness campsite impacts: effects of amount of use. Research Paper INT-284. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 34 p.

Cole, David N. Monitoring the condition of wilderness campsites. Research Paper INT-302. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983a. 10 p.

Cole, David N. Assessing and monitoring backcountry trail conditions. Research Paper INT-303. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983b. 20 p.

Cole, David N.; Schreiner, Edward G. S. Impacts of backcountry recreation: site management and rehabilitation—an annotated bibliography. General Technical Report INT-121. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 58 p.

Craighead, John J.; Varney, Joel R.; Craighead, Frank C., Jr. A population analysis of the Yellowstone grizzly bears. Bulletin 40. Missoula, MT: University of Montana, School of Forestry, Montana Forest and Conservation Experiment Station; 1974. 20 p.

Dana, S. T. Problem analysis: research in forest recreation. Washington, DC: U.S. Department of Agriculture, Forest Service; 1957. 36 p.

Echelberger, Herbert E.; Deiss, Daniel H.; Morrison, Douglas A. Overuse of unique recreation areas: a look at the social problems. Journal of Soil and Water Conservation. 29(4): 173-176; 1974.

Echelberger, Herbert E.; Leonard, Raymond E.; Adler, Steven P. Designated-dispersed campsites. Journal of Forestry. 81(2): 90-91, 105; 1983.

Echelberger, Herbert E.; Moeller, George H. Use and users of the Cranberry backcountry in West Virginia: insights for eastern backcountry management. Research Paper NE-363. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p.

Elsner, Gary H. Wilderness management . . . a computerized system for summarizing permit information. General Technical Report PSW-2. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1972. 8 p.

Field, Donald R.; Wells, Marisue; Flewelling, Robert. A computerized accounting system for backcountry use. Trends. 1977 April-May-June: 39-43.

Fox, Douglas G.; Murphy, Dennis J.; Haddow, Dennis, tech. coord. Air quality, oil shale, and wilderness—a workshop to identify and protect air quality related values of the Flat Tops Wilderness: Proceedings; 1981 January 13-15; Glenwood Springs, CO. General Technical Report RM-91. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1982. 32 p.

Frayer, W. E.; Butts, D. B. BUS: a processing system for records of backcountry camper use. Journal of Leisure Research. 6(4): 305-311; 1974.

Frissell, Sidney S. Judging recreation impacts on wilderness campsites. Journal of Forestry. 76(8): 481-483; 1978.

Frissell, Sidney S., Jr.; Duncan, Donald P. Campsite preference and deterioration in the Quetico-Superior canoe country. Journal of Forestry. 63(4): 256-260; 1965.

Frissell, Sidney S.; Stankey, George H. Wilderness environmental quality: search for social and ecological harmony. In: Proceedings, Society of Foresters annual meeting; 1972 October 1-5; Hot Springs, AR. Washington, DC: Society of American Foresters; 1972: 170-183.

Gilligan, James P. The development of policy and administration of Forest Service primitive and wilderness areas in the western United States. Ann Arbor, MI: University of Michigan; 1954. 625 p. Dissertation.

Godin, Victor B.; Leonard, Raymond E. Management problems in designated wilderness areas. Journal of Soil and Water Conservation. 34(3): 141-143; 1979.

Graefe, Alan R.; Vaske, Jerry J.; Kuss, Fred R. Social carrying capacity: an integration and synthesis of twenty years research. Leisure Sciences. 6(4): 395-432; 1984.

Habeck, J. R. Forest succession in the Glacier Park cedar-hemlock forests. Ecology. 49(5): 872-880; 1968.

Habeck, J. R. Fire ecology investigations in the Selway-Bitterroot Wilderness. Publication R1-72-001. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1972. 119 p.

Heinselman, M. L. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research. 3(3): 329-382; 1973.

Helgath, Sheila F. Trail deterioration in the Selway-Bitterroot Wilderness. Research Note INT-103. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 15 p.

Hendee, John C.; Catton, William R., Jr.; Marlow, Larry D.; Brockman, C. Frank Wilderness users in the Pacific Northwest, their characteristics, values and management preferences. Research Paper PNW-61. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968. 92 p.

Hendee, John C.; Clark, Roger N.; Hogans, Mack L.; Wood, Dan; Koch, Russell W. Code-a-site: a system for inventory of dispersed recreational sites in roaded areas, back country, and wilderness. Research Paper PNW-209. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 33 p.

Hendee, John C.; Stankey, George H.; Lucas, Robert C. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 381 p.

Herrick, Ramona. Wilderness preservation in North America: a conspectus and annotated bibliography. Ottawa, ON: Parks Canada (Ontario Region); 1974. 255 p. [Report prepared under the terms of contract 73-66, Pukaskwa National Park File No. 37/1-14, Final Code 4-01-304-1601-001-00-0406]

Hornocker, Maurice G. Stalking the mountain lion—to save him. National Geographic. 136: 638-655; 1969.

Houston, D. B. Wildfires in northern Yellowstone National Park. Ecology. 54(5): 1111-1117; 1973.

Hughes, Jay M. Wilderness land allocation in a multiple use forest management framework in the Pacific Northwest. Research Note PNW-26. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1965. 4 p.

James, George A. Inventorying recreation use. In: Recreation symposium proceedings; 1971 October 12-14; Syracuse, NY. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1971: 78-95.

Jungst, Steven E.; Countryman, David W. Two regression models for projecting future wilderness use. Iowa State Journal of Research. 57(1): 33-41; 1982.

Kellert, Stephen R. Perception of animals in American society. Transactions of the North American Wildlife and Natural Resources Conference; 1976: 533-545.

Ketchledge, E. H.; Leonard, R. E. The impact of man on the Adirondack high country. The Conservationist. Albany, NY: New York Department of Environmental Conservation; 25(2): 14-18; 1970.

Kilgore, B. M. The ecological role of fire in Sierran conifer forests: its application to national park management. Quaternary Research. 3(3): 496-513; 1973.

Krumpe, Edwin E.; Brown, Perry J. Redistributing backcountry use through information related to recreational experiences. Journal of Forestry. 80(6): 360-362; 1982.

Krutilla, John V.; Cicchetti, Charles J. Evaluating benefits of environmental resources with special application to the Hells Canyon. Natural Resources Journal. 12(1): 1-29; 1972.

LaPage, Wilbur F. Recreation and the forest site. Journal of Forestry. 60(5): 319-321; 1962.

Leonard, R. E. Design capacity: a possible approach to some backcountry recreation management problems. Appalachia. 42(2): 20-21; 1976.

Leonard, R. E.; Echelberger, H. E.; Plumley, H. J.; Van Meter, L. W. Management guidelines for monitoring use on backcountry trails. Research Note NE-286. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1980. 20 p.

Leonard, R. E.; Plumley, H. J. The use of soils information for dispersed recreation planning. In: Ittner, Ruth; Potter, Dale R.; Agee, James K.; Anschell, Susie, eds. Conference proceedings: recreational impact on wildlands; 1978 October 27-29; Seattle, WA. No.

R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979a: 50-63.

Leonard, R. E.; Plumley, H. J. Human waste disposal in eastern backcountry. Journal of Forestry. 77(6): 349-352; 1979b.

Leonard, R. E.; Whitney, A. M. Trail transect: a method for documenting trail changes. Research Paper NE-389. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p.

Leopold, Aldo. Wilderness as a land laboratory. The Living Wilderness. 6: 3; July 1941.

Lime, David W. Large groups in the Boundary Waters Canoe Area—their numbers, characteristics, and impact. Research Note NC-142. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1972. 4 p.

Lime, David W.; Lorence, Grace A. Improving estimates of wilderness use from mandatory travel permits. Research Paper NC-101. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1974. 7 p.

Lime, David W.; Lucas, Robert C. Good information improves the wilderness experience. Naturalist. 28(4): 18-20; 1977.

Lime, David W.; Stankey, George H. Carrying capacity: maintaining outdoor recreation qualities. In: Recreation symposium proceedings; 1971 October 12-14; Syracuse, NY. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1971: 174-184.

Lucas, Robert C. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Natural Resources Journal. 3(3): 394-411; 1964.

Lucas, Robert C. Redistributing wilderness use through information supplied to visitors. Research Paper INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 15 p.

Lucas, Robert C. Visitor characteristics, use patterns, and attitudes in the Bob Marshall Wilderness complex, 1970-82. Research Paper INT-345. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 32 p.

Lucas, Robert C.; Cole, David N.; Stankey, George H. Research update: what we have learned about wilderness management. In: Frome, Michael, ed. Issues in wilderness management. Boulder, CO: Westview Press; 1985: 173-188.

Lucas, Robert C.; Oltman, Jerry. Survey sampling wilderness visitors. Journal of Leisure Research. 3(1): 28-43; 1971.

Lucas, Robert C.; Stankey, George H. The role of research in applying the limits of acceptable change system. In: Watson, Alan E., ed. Proceedings, southeastern recreation research conference; 1985 February 28-March 1; Myrtle Beach, SC. In press.

Malm, William C. Introduction to visibility. Fort Collins, CO: National Park Service, Air and Water Quality Division, Air Research Branch; 1983. 51 p.

Manning, Robert E.; Potter, Fletcher I. Computer simulation as a tool in teaching park and wilderness management. Journal of Environmental Education. 15(3): 3-9; 1984.

Marion, Jeffrey L.; Merriam, L. C. Recreational impacts on well-established campsites in the Boundary Waters Canoe Area Wilderness. Station Bulletin AD-SB-2502. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1985. 18 p.

Mech, L. David. The wolves of Isle Royale. Fauna of the national parks of the United States. Fauna Series 7. Washington, DC: 1966. 210 p.

Merriam, L. C., Jr.; Smith, C. K. Visitor impact on newly developed campsites in the Boundary Waters Canoe Area. Journal of Forestry. 72(10): 627-630; 1974.

Murie, Adolph. The wolves of Mount McKinley. Fauna of the national parks of the United States. Fauna Series 5. Washington, DC: U.S. Department of the Interior, National Park Service; 1944. 238 p.

Murray, Judith Buckley. Appalachian Trail users in the southern national forests: their characteristics, attitudes, and management preferences. Research Paper SE-116. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1974. 19 p.

Muth, Robert M.; Clark, Roger N. Public participation in wilderness and backcountry litter control. General Technical Report PNW-75. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978. 12 p.

Nash, Roderick. The American wilderness. Forest History. 6(4): 2-13; 1963.

Nash, Roderick. Historical roots of wilderness management. In: Hendee, John C.; Stankey, George H.; Lucas, Robert C. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 27-40.

Nash, Roderick. Wilderness and the American mind. 3d ed. New Haven, CT: Yale University Press; 1982. 425 p.

Ohmann, Lewis F. Wilderness ecology: virgin plant communities of the Boundary Waters Canoe Area. Research Paper NC-63. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1971. 55 p.

Outdoor Recreation Resources Review Commission [ORRRC]. Wilderness and recreation—a report on resources, values, and problems. ORRRC Study Report 3. Washington, DC; 1962. 352 p.

Peterson, George L. Evaluating the quality of the wilderness environment: congruence between perception and aspiration. Environment and Behavior. 6(2): 169-192; 1974.

Peterson, George L.; de Bettencourt, James S.; Wang, Pai Kang. A Markov-based linear programming model of travel in the Boundary Waters Canoe Area. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest and Range Experiment Station; 1977: 342-350.

Peterson, George L.; Randall, Alan. Valuation of wildland resource benefits. Boulder, CO: Westview Press;

1984. 258 p. [Published in cooperation with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.]

Ream, Catherine H. Impacts of backcountry recreationists on wildlife: an annotated bibliography. General Technical Report INT-81. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 62 p.

Robertson, W. B., Jr. Fire and vegetation in the Everglades. Proceedings, Tall Timbers Fire Ecology Conference. 2: 67-80; 1962.

Roggenbuck, Joseph W.; Berrier, Deborah L. A comparison of the effectiveness of two communication strategies in dispersing wilderness campers. Journal of Leisure Research. 14(1): 77-89; 1982.

Rowe, Robert; Chestnut, Lorraine G. Managing air quality in national parks and wilderness. Boulder, CO: Westview Press; 1983. 314 p.

Schreiner, E. G.; Moorhead, B. B. Human impact studies in Olympic National Park. In: Proceedings, symposium on terrestrial and aquatic ecological studies of the Northwest; 1976 March 26-27; Cheney, WA. Cheney, WA: Eastern Washington State College; 1976: 59-66.

Shechter, Mordechai; Lucas, Robert C. Simulation of recreational use for park and wilderness management. Baltimore, MD: Johns Hopkins University Press; 1978. 220 p.

Sharsmith, Carl W. A report on the status, changes and ecology of backcountry meadows in Sequoia and Kings Canyon National Park. 1959. Unpublished paper on file at: Government Library, Sequoia National Park, CA. 125 p.

Speight, Martin C. D. Outdoor recreation and its ecological effects: a bibliography and review. Discussion Paper in Conservation 4. London: University College; 1973. 35 p.

Stankey, George H. Myths in wilderness decisionmaking. Journal of Soil and Water Conservation. 26(5): 183-188; 1971.

Stankey, George H. Visitor perception of wilderness recreation carrying capacity. Research Paper INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 61 p.

Stankey, George H.; Cole, David N.; Lucas, Robert C.; Petersen, Margaret E.; Frissell, Sidney S. The limits of acceptable change (LAC) system for wilderness planning. General Technical Report INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 37 p.

Stankey, George H.; McCool, Stephen F. Carrying capacity in recreational settings: evolution, appraisal, and application. Leisure Sciences. 6(4): 453-474; 1984.

Stankey, George H.; McCool, Stephen F.; Stokes, Gerald L. Limits of acceptable change: a new framework for managing the Bob Marshall Wilderness. Western Wildlands. 10(3): 33-37; 1984.

Stanley, J. T., Jr.; Harvey, H. T.; Hartesveldt, R. J. A report on the wilderness impact study: the effects of human recreational activities on wilderness ecosystems with special emphasis on Sierra Club wilderness outings in the Sierra Nevada. San Francisco: Sierra Club; 1979. 290 p.

Stone, Gregory P.; Taves, Marvin J. Research into the human element in wilderness use. In: Proceedings, Society of American Foresters annual meeting; 1956 October 15-17, Memphis, TN. Washington, DC: Society of American Foresters; 1956: 26-32.

Taylor, Dorothy T.; Mackoy, Robert D. Winter recreation in the White Mountains: users' characteristics and information needs. [Place of publication unknown]: Research Department, Appalachian Mountain Club; 1980. 103 p.

Temple, Kenneth L.; Camper, Anne K.; Lucas, Robert C. Potential health hazard from human waste in wilderness. Journal of Soil and Water Conservation. 37(6): 357-359; 1982.

Temple, Kenneth L.; Camper, Anne K.; McFeters, Gordon A. Survival of two enterobacteria in feces buried in soil under field conditions. Applied and Environmental Microbiology. 40(4): 794-797; 1980.

Wagar, J. Alan. The carrying capacity of wild lands for recreation. Forest Science Monograph 7. Washington, DC: Society of American Foresters; 1964. 24 p.

Walsh, Richard G.; Gillman, Richard A.; Loomis, John B. Wilderness resource economics: recreation use and preservation values. Denver, CO: American Wilderness Alliance; 1982. 107 p.

Washburne, Randel F.; Cole, David N. Problems and practices in wilderness management: a survey of managers. Research Paper INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 56 p.

Wenger, Wiley D., Jr. A test of unmanned registration stations on wilderness trails: factors influencing effectiveness. Research Paper PNW-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1964. 48 p.

Womble, Peter; Wolf, Wendy; Field, Donald R. Hikers on the Chilkoot Trail: a descriptive report. Seattle, WA: Sociology Studies Program, Cooperative Parks Studies Unit, College of Forest Resources, University of Washington; 1978. 70 p.

Wright, George M.; Dixon, Joseph S.; Thompson, Ben H. Fauna of the national parks of the United States: a preliminary survey of faunal relations in national parks. Fauna Series 1. Washington, DC: U.S. Department of the Interior, National Park Service; 1933. 157 p.

AUTHOR

Robert C. Lucas
Project Leader
Intermountain Research Station
Forest Service, U.S. Department of Agriculture
Missoula, MT 59807

THE WILDERNESS RESEARCH FOUNDATION

Glenn E. Haas and Michael J. Manfredo

ABSTRACT

The concept of a nonprofit, tax-exempt organization to support research related to the protection of our natural ecosystems was born in spring 1983. It was recognized that there was a lack of awareness, support, and coordination among individuals, institutions, and agencies involved in the scientific investigation of natural ecosystems. The Wilderness Research Foundation was created in response to this void.

The foundation was incorporated in the State of Colorado in May 1985 and formally introduced at the National Wilderness Research Conference on July 23, 1985. This paper describes the concept and direction of the foundation.

INTRODUCTION

The word "wilderness" was chosen as a generic concept which embraces all types of natural ecosystem land classification—national parks, national wildlife refuges, biosphere reserves, wilderness areas, and others. One commonality among these land classifications is the paradoxical question of how these areas can be managed unimpaired as naturally operating ecosystems while providing for their use and enjoyment by present and future generations.

There are a growing number of concerns to our societal goal of protecting natural ecosystems: visitor crowding; recreation use conflicts; disturbance and elimination of fish and wildlife species; deterioration of water quality; urban encroachment; air and noise pollution; and increasing consumptive demands. Public land managers, scientists, conservationists, artists, industrialists, politicians, and recreationists are beginning to recognize the complexity and challenge of this paradox. In response, under the corporate theme of "Learning to Preserve," the Wilderness Research Foundation has been established.

GOALS AND PROPOSED ACTIVITIES

The Wilderness Research Foundation will support wilderness through art, research, and information dissemination. It will serve to complement the activities of public land management agencies and conservation organizations in a nonpolitical and nonadversary role, without bias toward particular users or uses of wilderness.

Three foundation goals with associated activities are:

1. Increase the public's awareness of the importance of perpetuating an enduring resource of wilderness.
    a. Sponsor nationally prestigious wilderness art exhibits.
    b. Provide news releases to national media on the results of scientific studies.
2. Support high-quality research which will increase our ability to protect wilderness and its benefits for society.
    a. Obtain financial and in-kind resources for scientific research.
    b. Solicit research proposals and provide a rigorous peer review evaluation mechanism.
    c. Serve as a central administrative organization for multiorganization research and demonstration projects.
    d. Sponsor scientific studies and related activities such as think-tank retreats, development of interdisciplinary study plans, and demonstration projects.
3. Disseminate information among those involved in the protection of wilderness.
    a. Publish and distribute a periodic newsletter that would highlight foundation activities.
    b. Host workshops and short courses among public land management agencies and conservation organizations to facilitate information exchange.
    c. Publish and distribute a periodic monograph which focuses on critical issues (for example, water quality impacts, recreation carrying capacity, limits of acceptable change).

FOUNDATION DEVELOPMENT

The development of the Wilderness Research Foundation will occur in three phases. While the phases are sequential, various activities will occur throughout or be initiated as opportunities arise.

Phase I (Planning)

The first phase will occur over an 18- to 24-month timeframe and focus on: (1) developing a 5-year action plan; (2) developing a network of contacts among individuals, organizations, and agencies; (3) promoting the concept of "wilderness art" through a nationally prestigious annual wilderness art exhibit, (4) gaining media exposure of the theme "artists and scientists working together to preserve natural ecosystems"; (5) soliciting small financial and in-kind service contributions; and (6) submitting a 3-year seed grant proposal.

Phase II (Marketing)

The second phase will occur over a 36-month timeframe and focus on: (l) implementing a marketing and fundraising campaign; (2) initiating several highly visible research and information dissemination projects; (3) continued promotion of the annual wilderness art exhibit; and (4) the establishment of an endowment fund.

Phase III (Implementation)

The third phase will begin in 1991, at which time the foundation will be self-sufficient and support activities based on available monies from its endowment fund. It is projected that 5 years of developmental planning and marketing activities will be necessary before the foundation will be in a position to fully implement its proposed activities. The amount and type of support for these activities will increase over time as efforts to expand the endowment fund are successful.

FOUNDATION ADMINISTRATION

The foundation's mailing address is P.O. Box 9502, Fort Collins, CO 80525. The foundation will be guided by a Board of Directors and an Honorary Board of Advisors, composed of scientists, conservationists, artists, land managers, business people, politicians, and others. Its directors as of July 23, 1985, are:

Dr. Glenn E. Haas
Foundation President
Associate Professor
College of Forestry and Natural Resources
Colorado State University

Dr. Michael J. Manfredo
Assistant Professor
College of Forestry
Oregon State University

Mr. Leonard (Yank) Banowetz
General Counsel
Banowetz, Legget and Moore

Mr. Harry Crandell
Former Staff Director
Public Lands Subcommittee
U.S. House of Representatives

Dr. Jerry F. Franklin
Project Leader
Forest Ecology Research
USDA Forest Service

Mr. Curtis L. Gifford
Forestry and Agriculture Librarian
Colorado State University

Mr. Don Hatch, President
Hatch River Expeditions, Inc.

Ms. Joyce M. Kelly
Associate Director
President's Commission on Americans Outdoors

Dr. Robert C. Lucas
Project Leader
Wilderness Management Research
USDA Forest Service

Mr. Merrill Mehaffey, Artist

Mr. Paul C. Pritchard
President, National Parks and Conservation Association

Ms. Sally A. Ranney
President, American Wilderness Alliance

Dr. Robert G. Streeter
Chief, Office of Information Transfer
USDI Fish and Wildlife Service

Mr. Hollis Williford, Artist

AUTHORS

Glenn E. Haas
Associate Professor
College of Forestry and Natural Resources
Colorado State University
Fort Collins, CO 80523

Michael J. Manfredo
Assistant Professor
School of Forestry
Oregon State University
Corvallis, OR 97331

RESEARCH AND MANAGEMENT: A TEAM FOR THE WILDERNESS

Robert A. Jantzen

We are here to address a subject of common interest—wilderness. Although united on that front, there are nearly as many perspectives of what constitutes a "wilderness," what the priorities should be for its use, and what the management and research needs are, as there are participants at this unique conference. The concept of "wilderness" certainly varies with the user. Managers also have wide-ranging philosophies regarding resource values of wilderness. For example, managers concerned with social and esthetic aspects of wilderness have different management and research needs than those charged with managing the resource as a functioning ecosystem for fish and wildlife populations.

In the U.S. Department of the Interior's Fish and Wildlife Service, the wilderness concept is broad, extending beyond those lands designated as wilderness by the law of the land. It certainly includes those designated lands, but it extends also to the management of species that may exist in a single, pristine desert spring and to those species that traverse the North American Continent in their annual journeys from the Arctic to the Gulf of Mexico. Our agency is oriented to both the land base and habitats, and to the species that live there.

MANAGEMENT RESPONSIBILITIES

For 15 years, starting just 6 years after the passage of the Wilderness Act, the Fish and Wildlife Service has been managing lands legally designated as wilderness areas or as wild and scenic rivers. These lands total over 19 million acres or one-fifth of our entire 90-million-acre National Wildlife Refuge System. The lands, located in 25 States, represent an array of arctic, desert, tropical, coastal, riverine, grassland, and forest ecosystems.

The Fish and Wildlife Service also has management responsibilities, under other legislative mandates, for species and their habitats that require wilderness or natural ecosystem settings. These mandates include the Endangered Species Act and the related coordination, consultation, listing and delisting, and recovery work. One of our oldest legislative directives outlines migratory bird responsibilities under international treaties. Through the Pittman-Robertson Wildlife Restoration Act, we work through some State programs to support wilderness-related research and management. The Marine Mammal Act expands our responsibilities beyond our shorelines. These and various other legal authorities present us with an ever-challenging role in the wilderness management arena.

As you might imagine, our management concerns as an agency are as varied as the natural resources we manage, the legal mandates that guide our activities, and the public interests in our programs. Research and development activities in the Service have traditionally been a key component in the management of fish and wildlife resources. The origins of this research go back to the Bureau of Biological Survey in the early 1900's and the Office of Economic Ornithology, created in 1885. Early investigations provided a solid foundation of facts for the emerging resource management profession, thus establishing a precedent. The Service has continued the commitment to a management and research partnership; even under current economic conditions, we maintain a personnel staffing ratio of approximately five managers to one research scientist. The research function in the Fish and Wildlife Service receives its direction from management. This ensures management involvement in setting priorities for research and utilization of new information. It also ensures that the research activities stay attuned to the ever emerging and changing management needs. It is through this partnership, or team approach, that the Fish and Wildlfe Service develops and implements its management strategies, including those related to wilderness.

RESEARCH ACTIVITIES

The Service has many research activities that relate to wilderness management needs. I have grouped them into eight basic categories.

1. **Endangered species.**—Our research efforts on endangered species have a common goal—to learn enough about each species' life history and its habitat requirements so that natural resource agencies can implement management resulting in the delisting of the species. Our Moapa dace studies in Nevada, for example, have determined that this fish is unique to hot springs "microwilderness" settings, and has specific requirements for water chemistry, spawning substrate, and water velocity at each life stage. This information is being used by the Moapa National Wildlife Refuge staff to provide suitable habitat that now supports a new, larger population of this species, a major step toward recovery.

In a second example, life history relationships are being unlocked on a remote Wyoming ranch where a remnant black-footed ferret population was discovered.

Presented by Richard N. Smith, Associate Director-Research and Development, Fish and Wildlife Service, U.S. Department of the Interior.

Again, management recommendations are coming directly from the cooperative Wyoming Fish and Wildlife Service research effort to management.

We have research efforts continuing on the mountain caribou of northern Idaho, on the tortoises of the southwestern deserts, the gray wolf, and grizzly bear. The wolf and grizzly have become, perhaps, almost the standard-bearers of many wilderness advocates.

As we continue to unravel the biological requirements of each of these species, in their respective ecosystems, we incorporate that knowledge into a fact-based recovery plan. We fully hope one day that the population and habitats of these and other species can be enhanced to the point where the endangered species designation can be removed.

2. **Marine mammals.**—The Fish and Wildlife Service has management responsibilities for three species of marine mammals—sea otter, walrus, and polar bear. All are of special concern because of their commercial value, their significance to native Americans, and their requirements for a relatively undisturbed lifestyle. Each species is susceptible to overexploitation because of the remote, relatively fragile ecosystem of which it is a part.

We have ongoing research on the sea otter on the West Coast, and on all three species in Alaska. Additional work is needed to answer the major management questions of population status and trends and impacts of development activities on reproduction, survival, distribution, and movements. Development of the logistics and techniques required to work on these far-ranging species in the Arctic is a challenge in itself. Again, our research efforts are keyed to achieving specific management goals.

3. **Salmon.**—The Pacific and Atlantic salmon may not be generally thought of as wilderness species, because many stocks are heavily subsidized by fish culture operations. However, a major need in Alaska, on the West Coast, and in the Northeast is to preserve and protect the remaining natural spawning runs of these valued species.

In Alaska and the Northwest, natural spawning runs often occur in wilderness regions. Management of the many salmon stocks requires a complex information base on genetics, disease pathways, habitat requirements, and life history. The Fish and Wildlife Service has laboratories in Alaska, Washington, and along the East Coast, all working cooperatively to support salmon stock management and the role wilderness areas play in this management.

4. **Waterfowl.**—Waterfowl nest throughout the vast wilderness breeding areas in the Canadian and Alaskan tundra and boreal forests. Duck brood production and specific habitat requirements of this valuable wildlife resource continue to be priority management concerns because of gas and oil and other developments throughout the sensitive environment in these northern regions.

I cannot stress enough the importance of an adequate information base to provide guidance on when, where, and how each development can occur without impacting ducks, geese, and other aquatic birds. Our research efforts in Alaskan wilderness are currently focused on North Slope and Yukon Delta goose breeding populations.

5. **Land use impacts.**—An essential activity of Service work involves coordination with other Federal agencies charged with management of water, timber, forage, and recreation resources. We provide a major part of the biological analysis and mitigation planning for fish and wildlife on federally funded projects.

Studies on the effects of logging activities on avian and herptofauna in the Pacific Northwest and the effects of grazing management systems on arid lands and natural riparian communities and wildlife species in National Wildlife Refuges are providing direct management guidelines. Forestry and livestock operations can be positive management tools for fish and wildlife, even in remote and "natural" ecosystems.

Our coastal ecosystem studies are providing unique guidance for regulatory agencies and industry throughout the Gulf Coast. For example, the Service's detailed mapping of colonial wading bird nesting habitats and the development of habitat models to identify their habitat requirements are now commonly used tools for screening development sites and for planning restoration efforts.

Resource development will continue to occur in what we now consider to be remote, pristine ecosystems. We must have the biological facts that are derived only through diligent, directed research thereby ensuring protection for the fragile parts of each ecosystem and providing management options for those parts of the ecosystems that can be compatible with development.

6. **Acid precipitation.**—The complex ecological relationships impacted by acid precipitation are slowly being unraveled by various research investigations. One fact is clear: aquatic habitats in many wilderness areas are being affected by acid precipitation. Even in well-buffered lakes, our scientists have found that water quality is being threatened by the increased phosphorus available in acid precipitation and subsequent stimulation of phytoplankton growth, and eutrophication or aging of the lakes.

The Service is involved both in basic research on the effects of increased acidity on fish and their food chains and on mitigation techniques. Our research efforts and a concurrent operational field evaluation program are monitored by a management coordination group—an excellent example of how managers and researchers combine forces to produce maximum return on dollars spent.

A few of the mitigation options currently being investigated are applying acid-neutralizing materials, creating favorable microhabitats for fishery resources, stimulation of biologically produced alkalinity, manipulating sediments, developing resistant fish strains, and fisheries management modifications. Through these coordinated research and management actions we hope to remedy the aquatic ecosystems already impacted and protect susceptible systems until acid-producing emissions are controlled.

7. **Technologies.**—Researchers often have to develop a technique or tool before they can carry out their investigations. Many of these research tools are incorporated

by managers in operational programs. The following are some examples of research and development techniques our scientists have developed that have application in wilderness management.

The Instream Flow Incremental Methodology (IFIM) is one such technique. Water is a precious commodity, especially in the Western United States. Also, many of the National Wildernesses, Wild and Scenic Rivers, National Parks, and National Wildlife Refuges are either the source of valuable water resources or are dependent upon the waters within their boundaries. I suggest that managers consider using this modeling approach to document natural flows in nondesignated wilderness streams on Federal and State lands near metropolitan areas before court action occurs to adjudicate the urban area's fair share of clean water. "Proactive" management of wilderness water resources should be a priority for wilderness managers.

A computer-based planning tool we developed is called MOSS, a geographic information system. It has been accepted by several resource management agencies and is currently being applied on wilderness lands. It is a map overlay and area-analysis software package to aid in master planning of large geographic areas and for conflict resolution. It is a powerful tool for those who handle complex and multilayered spatial or map-based data sets.

Technology developed for research but with application for management is a remote sensing system to monitor the far-ranging movements of the Porcupine caribou herd in Alaska and Canada. The system consists of advanced radio transmitters that transmit both biological and locational data through satellite-based receivers to a computer system. The impulses are reduced to meaningful information on location, distance, and time of movements. The activities of the animals at each location are then integrated by a geographic information system onto habitat maps, also obtained by satellite-based remote sensors. The technique can be applied to any detectable species that occurs in remote locations. Direct management decisions on where to allow roads or when to restrict human interactions can be based on this type of information. The technique does require committing considerable resources. But when one is entrusted with management of valuable commodities such as wilderness areas, the cost is reasonable.

8. **Information transfer.**—I have emphasized, for each of the categories of Fish and Wildlife Service Research and Development, how we integrate research findings with management. We are dedicated to making the results of the research work and the expertise we have available to all Service managers.

Information transfer has paid off in bringing our research and management people into an even closer working relationship.

I believe it is important to get research results into the users' hands, and that the researchers must make an extra effort to do so. Thus far, I have emphasized a commitment to and the occurrences of the management-research team, and the use of factual information as the basis for sound decisions. I would be less than candid if I said it always happens in our agency. At times, decisions are made without adequate information, and sometimes without information that is available. In our form of government, political decisions play a major role in some of our management actions. Also, some managers don't have the time, or take it, to use the information at hand. Still others try but cannot find the information in time or it's just not available. I contend that managers of wilderness resources cannot afford to overlook information or data about the values, status, etc., of the resource base. Once it's gone, a "wilderness" resource is costly, if not impossible, to restore.

On the other hand, researchers are partially responsible for any management-research gap. They need to remain attuned to the types of management decisions being made and the related information needs. They have to ensure that their studies do support and can be related back to the priority management questions. Researchers need to go out of their way to communicate their results in management terms.

RESEARCH PRINCIPLES

I'd like to close with some principles that apply to wilderness research that I think are important. First, a management-research team has to have a positive, cooperative, mutually supportive attitude. There needs to be an openness and willingness to share and explore ideas. Team members must be willing to change attitudes and perspectives when the management environment (goals and managers) changes and when new biological information becomes available.

Second, wilderness managers have to involve the researchers in the management process. Researchers have to get involved in management problems to help identify the key research (and researchable) issues. Managers should work with researchers and use various modeling approaches as planning tools to identify system relationships and priorities.

Third, managers must be willing to pay the price, financially and in time, that sound research requires. Advance planning and long-term research must be balanced with brushfire types of studies. Both are needed by managers; both have their advantages and costs.

A fourth principle is that researchers, even in wilderness settings, must make full use of controlled design experiments versus strictly observational, naturalist approaches. We must have more "cause-effect" studies that address clearly identified management questions. This is a more cost-effective means of addressing priority problems. This principle may cause some philosophical discomfort among some of those into the pursuit of knowledge for the sake of pure science. I am speaking as a public official who is committed to and supports a sound research program but one who frequently sees a strong need for a more scientific, quantitative approach to research studies.

Last, and perhaps the real "bottom line," is that managers must be willing to implement research findings. They must be willing to adapt their ways of doing business, their decisions, to make full use of the technical knowledge available to them. Modern wilderness managers must be visionary, "proactive" decision makers, basing their actions on today's best biological knowledge but with an eye for the future.

With a solid team approach to wilderness research and management, I believe resource agencies can manage all sizes, shapes, and degrees of wilderness for the protection of the valuable resources associated with them, and the enjoyment of all those yet to come.

AUTHOR

Robert A. Jantzen
Director
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

MANAGING OUR WILDERNESS HERITAGE

Robert F. Burford

It is a great pleasure to be back in my home State of Colorado. I am proud that Colorado State University has taken the lead in organizing this conference. The Bureau of Land Management recognizes research as a vital tool in managing wilderness areas, and is appreciative of the opportunity to serve as a cosponsor of this conference.

Wilderness is an important part of America's heritage. Wilderness areas deserve the best care and the most thoughtful management we can give them. As Federal land managers, we tend to get caught up in the day-to-day considerations over which lands should be designated as wilderness, and which should continue to be managed for other values. Once the Congress has acted, however, and designated an area as part of the Wilderness Preservation System, it is time to unite in a consensus effort to manage these areas the best way we know how. If we succeed, today's wilderness values will be there for our children, and their childrens' children to enjoy.

During the past year, Congress designated the first large areas of BLM lands as part of the National Wilderness Preservation System. We now have 370,000 acres, in 23 different areas, spread over eight States. These areas contribute significantly to the diversity of the Nation's dedicated wilderness system.

BLM's 23 areas are just the beginning. Unlike the other three wilderness agencies, BLM received a wilderness mandate from Congress only 9 years ago, and we are still in the midst of our wilderness study program. The findings of those studies will be submitted to Congress over the next few years, and no doubt new BLM wilderness areas will follow.

FUTURE DIVERSITY

Judging by the lands under study—about 25 million acres—future BLM wilderness areas could be very diverse. The lands range from arid desert to whitewater rivers—from towering canyons to dry lakebeds—from sagebrush flats to mountain meadows. In fact, very few BLM areas resemble the classic Forest Service wilderness, with mountain peaks and glacial lakes. Many BLM wilderness areas will be drier and flatter.

It has been said that BLM lands are "the lands nobody wanted." We all know that is changing. From where I sit, they have become "the lands everybody wants."

Not only is there tremendous competition among the major users of the lands, ranging from mineral development to recreation, but there is also competition within each category of use.

This competition exists even among wilderness users themselves. In some areas, for example, we've even adopted measures to prevent recreational overuse. A case in point is the Aravaipa Canyon Wilderness in Arizona, where we have had a permit system in place for several years, limiting overnight visitors to 50 people per night.

In keeping with the Reagan Administration's policy against unnecessary and burdensome regulations, we would prefer to deal with such problems in other ways. Because people come to designated wilderness areas to escape the restrictions and regimentation of everyday life, we manage these areas to protect their unique values, in a manner least intrusive on their human benefactors.

This is one area where research can help.

We in the BLM have been attentive to the solid research already conducted by our sister agencies and the academic community. For example, our manual section on wilderness incorporates concepts that originated in Forest Service research efforts. We will continue this effort to profit by all research that we can apply to our on-the-ground management situation.

NEEDED RESEARCH

In addition, however, we will need research with a different emphasis. I will mention two examples.

In the arid climate of many BLM areas, impacts caused by recreational uses are slow to heal. So rehabilitation of overused campsites will be a real challenge. Another problem shows up in canyon country. Here, visitors are often concentrated into relatively small areas, and there doesn't appear to be much we can do to disperse this use. We are looking for some sophisticated thinking from the research community on problems such as these.

We also need help in the areas of insect infestations, management and rehabilitation of burned areas, and problems of wildlife management, both in and adjacent to wilderness areas.

As a newcomer to wilderness management, BLM is open to adopting the most innovative approaches to wilderness management. We are therefore in a position to apply new research findings immediately.

As each BLM wilderness is designated, our field offices will begin to develop a wilderness management plan for each individual area. These plans will offer our first opportunity to address the issues and problems specific to the area. We will attempt to incorporate good research findings, new ideas, and innovative solutions into our planning.

We already have a highly professional cadre of wilderness specialists on the job. Most of them have worked on the wilderness studies, and we are now utilizing these professionals for wilderness management activities, as we enter that phase of the program. We are also encouraging all of our wilderness managers to keep in touch with the research community, and to keep up to date on the latest research results. Some of our managers are attending this conference, and we will disseminate the conference proceedings widely among BLM field officials.

By the same token, I urge you who are doing research to keep the BLM in mind. BLM wilderness areas will present some challenging new problems that deserve—and will benefit from—your attention. I invite you to keep in touch with BLM wilderness managers, who can suggest specific research topics.

If you need somebody to put you in touch with the most appropriate field people, please call or write to our Branch of Wilderness Resources in our Washington office. David Porter, who heads that office, is here at the conference, and he will participate in the panel discussion this Friday.

The BLM has a very small appropriated budget to support all the wilderness research we need. Given the desire to reduce budget deficits, I do not foresee any significant increase in the next 2 years. So we are dependent upon your institutions and your ingenuity for conducting the needed research projects. As you discuss research needs with our field offices, however, they may be able to assist you in a variety of ways.

SETTING PRIORITIES

For the past 4 years I have spent much of my time as Director dealing with budget matters, trying to make sure BLM is appropriated the money it needs to take care of the public lands. The competition for funds is intense, both among the programs within BLM, and among the various parts of the Federal Government. And it's not going to get any easier. We must ensure that research projects are cost effective and make the largest contribution possible to improving management of these areas.

When thinking of wilderness research across the board, we really cannot afford to spend research money on projects of only passing interest. We could do a host of ad hoc projects that help individual areas, and yet totally miss the big picture.

The challenge is to focus on that big picture—and to develop a systematic action plan for wilderness research over the next 10 years. I am confident that if the ideas discussed at this conference are pulled together by a follow-up task force, you could come up with a 10-year action plan that would point the way toward research that is cost effective and gives us the answers we need.

We are fortunate to be the stewards of the National Wilderness Preservation System. We follow in the footsteps of others who conceived the wilderness idea, and we will be followed by other generations of stewards. If we do our job right, wilderness areas will be handed to the next generation in as good condition or better than we found them. Wilderness research is helping us in many ways to do that. I salute your efforts. And I look forward to your future successes in helping us to preserve our wilderness heritage.

AUTHOR

Robert F. Burford
Director
Bureau of Land Management
U.S. Department of the Interior
Washington, DC 20240

WILDERNESS RESEARCH: AN IMPORTANT LINK TO WILDERNESS MANAGEMENT

R. Max Peterson

This conference is very important to me, because managing wilderness is a vital part of the Forest Service's multiple-use mission. The Forest Service's interest in, and support of, wilderness has a long, proud history, and that interest both includes and is built on wilderness research. We have happily endorsed the new Wilderness Research Foundation and view it as a major, positive happening.

We are pleased with the addition of more than 6½ million acres of wilderness to the National Forest System over the last few years. The new additions doubled the number of designated National Forest Wildernesses and extended wilderness management responsibility to 92 percent of our Forest Supervisors. Of the 122 National Forests, 112 now have at least one wilderness. So we are strong supporters of wilderness. We believe in wilderness and its value to the American people and to the world in general.

A CHANGING FOCUS

The issues of how much wilderness is good and desirable and what areas should be given wilderness designation will never completely be resolved. However, we believe the forest land management planning process, in coordination with the legislative process, is the appropriate place to resolve the remaining quantitative questions of wilderness. We must now focus more attention on qualitative issues of wilderness management.

As was so aptly stated in the theme of the 1983 National Wilderness Management Workshop in Idaho, we must direct our energy toward "taking care of what we've got."

My challenge to the managers and researchers in the Forest Service is, now that we are stewards of more than 32 million acres of wilderness, what do we do to gain the most public benefits from this enduring resource of wilderness?

Last December at a meeting marking the 20th anniversary of the Wilderness Act, I stated some wilderness management principles that guide us, and I'd like to briefly restate them for you.

These wilderness management principles are grounded in the Wilderness Act, and direct that we should:

- Allow natural processes to operate freely;
- Maintain outstanding opportunities for solitude;
- Do necessary management work in wilderness without motorized equipment or mechanical transport whenever possible;
- Gather scientific information without the intrusion of permanent improvements or motorized equipment; and
- Manage special exceptions provided in wilderness bills for individual areas, while protecting wilderness values and keeping the 1964 Act as our basic guide.

However, as much as we talk about managing wilderness, our primary task is really to manage people who use wilderness, including our employees.

A key to properly managing people is to help them become knowledgeable about wilderness. This education element was an important theme at the 1983 Wilderness Management Workshop. A steering committee formed from that conference, and chaired by Dr. Edwin Krumpe, has recently released an excellent 5-year action program for improving wilderness management. Ed will present a report on the action program later today.

The steering committee's action plan does an excellent job of providing a sense of direction. Now it's up to all of us to start moving purposefully in that direction. Now that we've got a framework, we must continue building a sound wilderness management program. Wilderness research is an important element in our efforts.

RESEARCH RELATIVELY NEW

Wilderness research, both basic and applied, is a relatively new area. However, we've accumulated centuries of combined experience in wilderness management since the Forest Service established the first Wilderness Area on the Gila National Forest more than 60 years ago. A worthwhile, short-term research project would be to capture the knowledge that has come from this experience. Let's not lose it!

One of the reasons we need research in wilderness is to help us better understand this resource. Two of the key concepts stated in the Wilderness Act are that wilderness is ". . . an area where the earth and its community of life are untrammeled by man . . ." and which ". . . has outstanding opportunities for solitude or a primitive and unconfined type of recreation." There are basic questions we must ask. What makes a particular ecosystem operate? What are the area's natural processes, and what effect do human and uncontrolled natural forces have?

Presented by Roy Feuchter, Director, Recreation Management Staff, Forest Service, U.S. Department of Agriculture, Washington, DC.

What are the effects of human interaction on the natural processes, and how severe are they? What effects do pollution sources from outside the wilderness have on the air, water, and vegetation within the wilderness?

But perhaps even more basic, or at least of potentially more impact, is the question of how do we build a wilderness ethic or nurture that which exists? What are the most efffective education techniques? Where and when should we direct our communication? How do we structure our message that wilderness is more than simply recreation in a primitive environment? It is important as a resource! It is needed as a resource! It should not be used to prevent something else. I don't know if research can help us clarify this distinction, but I do know they must not add to the problem; and I suggest we all need to review our motives in this regard.

Perhaps the toughest question of all, because it may be the key to maintaining wilderness in the future, is how do we manage, without destroying, the unmanaged experience that is fundamental to all wilderness? Our agency intention is to manage wilderness, to continue to improve our management, and to sponsor and conduct research to that end.

GOAL IS QUALITY

Our goal is to maintain the quality of wilderness and to provide an "enduring resource of wilderness." We fully expect this will require constraints, limits, and restrictions, and that some of those restrictions will conflict with either existing activities or future activities that may in themselves be valid, and either useful or needed endeavors. Some may be strongly in the public's interest but may lose out to the national need to protect and maintain wilderness.

It is our intention that wilderness management will not be "business as usual." We will strive for purity—in the short run, as much as reasonably possible, and in the long run, always! This will not be without heartache. In fact, there may often be weeping and wailing and gnashing of teeth as special interests see their "ox being gored." To some extent there are no easy answers, and there will be some points we lose in the political halls. That is part of our political system, as long as professionals provide their proper input.

But there is also the potential and opportunity to ease much of the pain, resolve problems, and lessen impacts partly through intelligent, common-sense management, and partly through research that sets out to help solve management problems.

Conferences like this can help identify those problems and research needs. An example is the need to provide the social research background for that problem I call the toughest of all: How will we regulate, limit, and restrict without stealing the feeling of freedom and unconstrained adventure from the wilderness use?

Wilderness managers should work very closely with scientists to recommend and develop research programs so that we do not waste precious research time and dollars on efforts that are not top priority or related thereto. A good example of excellent teamwork between Forest Service wilderness researchers and managers is the development and testing of the Limits of Acceptable Change concept. This concept is currently being tested in several wildernesses throughout the National Forest System. I believe it can help us maintain the quality of wilderness, and it's an especially important concept for the management of the recreation resource within wilderness.

We must be careful, though, that it is well understood and applied correctly. It must not be used to simply zone wilderness so that lower standards can be justified for some areas. Nor must it be used to allow uncontrolled increases in wilderness use or degradation in the name of special conditions or problems. Rather, it should be a technique that recognizes special conditions and helps us maintain a high quality of wilderness, even when conditions vary within a given area.

There is no doubt that when people visit wilderness some changes must occur. However, we must adapt or limit the change to meet our responsibility of maintaining the wilderness character. The pressure will always be on the managers to allow more use or to accept something "less natural." Perhaps a better name for the wilderness management concept would be "Acceptable Limits on Change Imposed by Wilderness!"

ACT LEADS WAY

Managers must be diligent in setting standards so we can be sure we comply with the Wilderness Act. The Act directs that our management of areas ". . . leave them unimpaired for the future use and enjoyment as wilderness, and . . . provide for the protection of these areas, the preservation of their wilderness character . . . ."

Researchers, when planning research within a wilderness, are presented a special challenge by the Wilderness Act. The gathering of information about resources within wilderness must be done ". . . in a manner compatible with the preservation of the wilderness environment."

This means that unless justified ". . . to meet minimum requirements for the administration of the area . . ." data must be gathered without permanent structures or the use of motorized equipment and without intruding on the visitors' solitude. This makes the researchers' tasks more difficult, as it does managers', but neither management nor research can afford to violate wilderness.

It's a big task—worthy of our best effort—because the benefits of an "enduring resource of wilderness" are even bigger than the task!

AUTHOR

R. Max Peterson
Chief
Forest Service
U.S. Department of Agriculture
Washington, DC 20250

THE NATIONAL PARK SYSTEM: THE CHALLENGE AHEAD

William Penn Mott, Jr.

It is a pleasure to appear before you today to discuss a topic very dear to me—the future of the National Park System. As you well know, I came to the office of Director of the National Park Service with a very definite vision of where I believe the future of the National Park Service lies, and I am delighted to see this very issue discussed in many corners of our society, and those of other nations.

These discussions are now beginning to converge, to come into focus, as is evidenced by the efforts of the Conservation Foundation in their recent publication, "National Parks for a New Generation: Visions, Realities, Prospects," the International Union for the Conservation of Nature and Natural Resources (IUCN) as they develop and test their computer system to establish and monitor the status of parks and protected areas worldwide, and Secretary Hodel's new initiative to increase public awareness and involvement with all publicly owned land resources. It is this type of creative thinking that will be of great help as we open up a dialogue and draw on the creative energies and problem-solving approaches of all constituencies, at the local, State, national, and international levels, to chart our course carefully for the future.

While the National Park Service has served this Nation's conservation community well since the establishment of Yellowstone National Park in 1872, the Service has also shared with other nations the value of parks and protected areas. In fact, through the International Parks Seminar, we have trained a large majority of the current directors of various park systems throughout the world. In the past, we have clearly demonstrated leadership, and it is my intention that the National Park Service will, as we chart our course for the future, lead the way toward a greater understanding of such critical issues as the role of parks and protected areas in the fields of biological diversity, integrated regional and ecosystems planning, the systems approach to park management based on an adequate data base and understanding of the resources under our stewardship, and the evolution and survival of our cultures. We intend to provide positive, direct, and creative leadership to speak to issues and set standards of administration and maintenance for others to follow.

Critical to the dialogue that we are opening up is an ongoing discussion with Members of Congress. Not only does each Congressman impact policy as various legislative issues are deliberated, but it is the Congress that considers our budget requests, which directly influences policy. When we consider some budgets of other Federal bureaus, the National Park Service budget seems small; but the job it does, from a quality of life point of view, is quite large. In fact, I view it as an investment in our future, the future of our children, our grandchildren, and our great-grandchildren.

BROAD OBJECTIVES

As we begin to chart our course for the future, I believe that we need to look objectively at the state of the National Park System today with its 337 units and 79.5 million acres of land visited by 350 million, one-third of a billion, people annually. We must decide what actions should be taken to preserve this legacy for future generations.

In that light, we must seriously begin to think about the relationship of Federal agencies with each other so that one agency does not take action that will harm the efforts and mission of another and that systems at the Federal, State, and local levels relate to each other harmoniously. I believe sincerely that a united, working-together, interrelated system can meet the ever-increasing demands of the visiting public without serious damage to the natural and cultural values of park systems everywhere.

We also need to be able to forecast and forestall those technological and environmental changes that could result in irreparable damage to the natural and cultural resources that are entrusted to our stewardship. Further, we in the National Park Service need to rededicate ourselves to serving the millions of visitors who come to our National Parks so that they can enjoy, appreciate, and take pride in our national heritage under quality conditions and through a professionally established and well-trained group of interpreters with skills to bridge the gap between the urban culture of our society and the natural world.

THE 12-POINT PLAN

To more carefully define these broad objectives, I have developed a 12-point plan that I believe is crucial to our future. I have developed these 12 points from my 50 years of experience as a practicing park professional and in consultation with the 10 regional offices of the National Park Service and the directorate in the Washington office. In fact, I discussed these specific points with Secretary Hodel as a basic condition of my acceptance of the position of Director of the National Park Service; and he has given me his full support.

At a meeting with the regional directors and constituency groups at Yellowstone National Park in June of this year, I shared these ideas. At that time, I challenged the regional directors and service center managers to begin making opportunities out of what may be perceived as "problems." This is one of my personal philosophies in life that has stood me well, and I intend to encourage this philosophy during my tenure as Director of the National Park Service.

In my challenge to the regional directors and service center managers, I specifically asked that each one of them become personally involved in these 12 points by each selecting one point, approaching the issue creatively, and developing an implementation plan. My 12-point plan has now been published in booklet form and the implementation process now begins. Because I need the awareness and support of organizations such as this group, I would like to take this opportunity to share with you the highlights of my 12-point plan.

1. Develop a long-range plan or strategy to better protect our natural, cultural, and recreational resources. It is absolutely essential for us to develop broad, new concepts for better protection of our resources over the next 50 to 100 years. The directions that we gain from these concepts should ultimately be viewed as the "hallmark" of contemporary thought concerning resource protection. It should be the very best that we can do. I expect us to involve the best "minds," both within the Service and outside, to produce, in a highly professional manner, the concepts that will give focus to our management decisions and provide guidance for expanding our research efforts to meet critical needs.

2. Pursue a creative, expanded land-protection initiative. Additional lands must be made available to meet public demands and round out the system for increased use and for the protection of this Country's natural and cultural heritage. Some of this acquisition must be met through fee acquisition. However, I do feel that we have not used other innovative acquisition strategies involving States, other Federal agencies, and the private sector as extensively as we might. Changing economic conditions indicate that we must expand these avenues not only because of the limited funding we face, but because, frankly, these other not-for-fee acquisition possibilities offer us some real opportunities and challenges to provide for the public and the resources. This flexibility also could offer additional acreage without large expenditures of money.

We need to change our approach and attitude toward land acquisition strategies. To understand these new techniques, it may be desirable to have a workshop as well as training opportunities or personnel exchanges not only to review the diversity of land protection strategies, but also how best to manage such lands. We need also to revalidate our ideas.

3. Stimulate our interpretive and visitor services responsibilities for greater public impact. For too long, we have not realized the power of interpretation in helping us achieve the mission of the Service. Every point of public contact represents a tremendous opportunity for us to build public support for the National Park System and to educate our now-predominantly urban population on the natural and cultural values found in the National Park System, and also how the public can best appreciate these priceless assets and protect them for future generations to enjoy.

I feel we must emphasize the broader context within which the units of the National Park System are managed. We must "weave" into this a focus of understanding how parks contribute to the quality of life and productivity in our country and throughout the world. Interpretation and visitor service functions must be "infused" with new ideas and a broader vision of parks.

4. Effectively share our understanding of critical resource issues with our publics. Obviously, we don't know all the answers to solve the critical resource issues we face, but we have an obligation to share what we do know. On many complex issues, such as historic preservation, acid deposition, critical habitat loss, and endangered species management, we can present these concerns in a context of public understanding. A public that understands, and shares its understanding with our elected officials at all levels, is a very powerful force.

5. Increase public understanding of the role and function of the National Park Service. We must communicate more effectively and more frequently with the public exactly what we are planning to do as well as what we have accomplished. At the park level, we must involve the local communities in what we are doing and how it relates to them. Perhaps a public statement at the beginning of each year that defines what we hope to accomplish for the year would be a good first step.

At the Washington level, I expect to present to the Administration and to the Congress an annual report. This will summarize the work and accomplishments of the Service during the year, together with a statement of our fiscal accountability.

I would also like to let you know that I will encourage each superintendent to provide me with a one-page report every 6 months on what is taking place in that park unit. I plan to transmit these reports to Members of Congress who have units of the National Park System in their districts.

6. Expand the role and involvement of citizen groups at all levels in the National Park Service. In my experience, some of the best ideas and most stimulating thoughts for improved management and development of parks have come from an interested and involved public. We need these groups and individuals to be involved in meaningful ways. They tend to recognize problems as opportunities. They see the world from a different perspective. In an era of accountability, the close involvement of citizen groups to provide constructive criticism, support, and a different way of thinking can be invaluable.

7. Seek a better balance between people management and resource management. We have areas, in my judgment, that may be out of balance. It seems we unintentionally ignore the public in some areas and we err in others by ignoring the resource. I feel this lack of balance often creates issues that put the Service in adversary roles with some of the public. In carrying this out, I will review closely our management philosophies for

balance, visitor use, and resource protection, and the guiding research which provides the information needed to determine that balance.

8. Enhance our ability to meet the diverse uses that the public expects of the National Park System. Obviously, we cannot and should not provide for every use or activity that the public would like to have in every unit of the National Park System; but, my question is, "Are we being as flexible as we can, consistent with legislation?" If we are already as flexible as we should be, then we may need closer involvement with others—States, Federal agencies, and the private sector—to provide some of the activities expected of us. By working with the park systems at the State and local levels, we will be able to identify where the most appropriate activity can be found; and, again, we need to let the public know where they can be served, rather than telling them "no."

9. Expand career opportunities for all employees. In my judgment, the success that has been enjoyed by the National Park Service rests with the trust and respect that the American public has for the competent, dedicated employees of the Service. Everything we hope to do must foster this tradition of obtaining and keeping a productive workforce.

We must ensure that our most capable employees are placed in the most demanding, challenging opportunities that the Service can offer. We must constantly seek new ways to challenge our employees to achieve excellence. And we must develop new ideas that will provide for career enhancement. I know that there has been some excellent work done on this important subject, and I intend to build on that.

10. Provide for appropriate planning, design, and maintenance of park facilities. Over the past 5 years, the National Park Service has made inroads, with Administration and Congressional support, into bringing park facilities up to standards that visitors and employees have a right to expect. With the progress that has been made, comprehensive preventive maintenance becomes an essential, continuing element in our management program. We will use the latest appropriate technology as well as a "creative systems" approach to accomplish this important task effectively and efficiently. It represents 45 percent of our total operating budget in fiscal year 1985. Planning must meet the needs of the public and management simply and in harmony with the resources of the area. Costly, overdesigned buildings must not be allowed. This does not, however, mean that quality in construction will be sacrificed. To the contrary, we will constantly strive for quality not only in our planning and construction but, also, in our management and maintenance of the units of the National Park System.

11. Develop a team relationship between concessioners and the Service. I would like to develop a more cooperative relationship between the Service and the concessioners so that they become a part of the team. We want their operations to reflect the same quality and attention to the public's needs as is demonstrated by the Service itself.

12. Foster and encourage more creativity in the management, administration, and communication of the National Park Service. Any organization that hopes to be successful during the rapid changes we face today must be extremely creative in the way it views its mission and in the way it carries out its responsibilities. The freedom to take "calculated risks" must be one of our guiding principles. We must evaluate all ideas, both old and new, for appropriateness to the situation we face. I will initiate actions to make an overall assessment of this bureau's capability to carry out this mission creatively and with the flexibility that today's changes require.

FUTURE IS BRIGHT

These are the key points that I believe are critical to the future of the National Park System. In the past, the National Park Service has met its challenges with direction and commitment. However, times are changing rapidly, and with these changes we need to sharpen our skills, dedication, and ability to meet the complexities of the future. With your help, along with that of our other constituencies and our public, I firmly believe the future is bright and that we can pass on to future generations for their enjoyment and use a National Park System unimpaired.

AUTHOR

William Penn Mott, Jr.
Director
National Park Service
U.S. Department of the Interior
Washington, DC 20240

SCIENTIFIC USE OF WILDERNESS

Jerry F. Franklin

ABSTRACT

Relatively little scientific use has been made of wilderness areas despite the outstanding opportunities they provide for research. Examples are given of the applicability of wilderness-based research to solution of problems outside wilderness areas, such as those on commodity lands. Deterrents to research include attitudes of scientists and managers, restrictions on equipment and sampling techniques, and conflicting human activities. Suggestions are made for increasing the level of wilderness research.

INTRODUCTION

Science has been used as a justification for protecting wilderness areas since the beginning of the wilderness concept. Proponents have emphasized the value of such natural areas for baselines; that is, to provide for comparisons with managed landscapes, for studying ecological processes, and for preserving gene pools. The interaction of science and wilderness has scarcely gone beyond the rhetoric and printed texts, however. Very little scientific use has actually occurred, and even less consideration has been given to scientific values in management planning, programs, and developing wilderness regulations.

Increased scientific use of wilderness is needed to demonstrate its important potential value to society as well as the contribution that science can make to wilderness. The current low scientific use clearly makes less credible this major justification for the wilderness system. Lack of research also reduces the amount of scientific information available for identifying and solving management problems.

In this paper the potential of wilderness for science is reconsidered and examples of the relevance of wilderness-based information to intensively managed landscapes are provided. Problems contributing to the low scientific use of wilderness, including conflicting uses and regulations, are also considered. Some steps are suggested that could help nurture science within wilderness areas. My intention is to stimulate the extensive collaboration between wilderness managers, users, and scientists that will be necessary for society to extract the priceless information contained in our wilderness system.

ECOLOGICAL PROCESSES IN WILDERNESS ECOSYSTEMS

Fundamentally, wilderness ecosystems are just like other ecosystems in their basic attributes of structure, function, and process. There are cycles of water and of nutrients, just as in nonwilderness ecosystems. Productivity occurs as energy from the Sun is captured through photosynthesis and converted to organic materials. Organic materials are ultimately decomposed in a multitude of detrital pathways.

Within wilderness ecosystems are patterns of disturbance and recovery, equilibrium not being a normal natural condition. Primary succession or ecosystem development occurs, as on recently bared deposits of glacial till. Complex patterns of secondary succession develop after traditional disturbances, such as the wildfires that so many wilderness ecosystems have adapted to, or powerful, large-scale disruptions, such as those associated with volcanic eruptions.

Wilderness ecosystems are sites for an array of ecological interactions, as are all ecosystems. They provide habitat for a variety of organisms and sites for complex animal and habitat interactions. Interfaces, sites of material transfers, occur between terrestrial and aquatic ecosystems. Wilderness ecosystems are, thus, essentially the same as any other ecosystem in the structures, functions, and processes that are represented. The uniqueness of wilderness ecosystems comes from other attributes.

UNIQUENESS OF WILDERNESS ECOSYSTEMS

Wilderness ecosystems are unique in their scale and in their degree of naturalness, which provide people with unique opportunities to learn.

Scale refers to the occurrence of large areas with a high degree of integrity and continuity within wilderness. But wilderness landscapes can also have a high degree of complexity or diversity. The grand scale and complexity provide unique research opportunities (Franklin 1981). For example, we can study undisturbed aquatic and wetland ecosystems at the geographic scale of an entire river drainage. Interactions between biologic and geomorphic processes can be examined, as in relations between forest conditions and fluvial processes (for example, erosion and flooding). Investigations of animal populations, including large herbivores and wide-ranging predators (for example, elk [*Cervus elaphus*] and cougar [*Felis concolor*]) are possible. Wilderness landscapes allow us to look at patterns of diversity in composition and structure and to see how these are related to environmental factors and disturbances; examples are the size and shape of natural patches and the forms of boundaries or ecotones between patches that result from natural fire.

Naturalness, the second distinguishing feature of wilderness, refers to relative freedom from human and other external influences. It reflects "wildness," an attribute that makes the areas valuable as natural baselines. This fact was noted by Stanley Cain many years ago: "Wilderness areas are the only yardsticks we have—or can have—of the long-continued interactions of natural ecological laws. . ." (Sierra Club 1964). This is why wilderness areas are sought today as sites for studies of global background levels of pollutants, CO_2, and other substances. The initial study sites in the United Nations Environmental Programs's Global Environmental Monitoring System (GEMS) are, for example, in the wildernesses of Olympic National Park (Washington State) and Torres del Paine National Park (Chile). An important aspect of the naturalness in wilderness is that it refers to processes currently under way as well as to historic impacts; hence the value of wilderness in monitoring programs.

Scale and naturalness are central to the outstanding value of wilderness for society generally and science specifically.

WILDERNESS AS A SOURCE OF INFORMATION

It is my view that wilderness has two primary values to humanity: information and inspiration. Philosophically, it can be argued that these are one and the same; however, I want to single out wilderness as a source of information—information that takes many forms. There is the genetic information encoded within species; wilderness areas contain some of the few remaining, large, natural gene pools of organisms. Historical information is contained in individual organisms, such as the tree-ring chronologies of the bristlecone pines (*Pinus aristata*). There is information on community processes, such as patterns and rates of tree mortality. And there is information on landscape-level processes, such as effects of fire and windstorms, which are often periodic and large-scale phenomena.

I want to emphasize that I am talking about information of broad value in our lives and activities **outside** the wilderness, although such information is almost always of interest and even of practical use to the wilderness manager. I am not talking primarily about research and information needed for management of the wilderness, which is an important but separate and less cosmic issue.

Examples are numerous of applying information from natural ecosystems to important problems or to resolving resource management issues in managed ecosystems. One of my favorite examples is the lesson that old-growth forests have taught about the importance of the dead tree both in its standing form (as a snag) and as a downed log (Franklin and others 1981; Maser and Trappe 1984). These dead structures serve many functions in both aquatic and terrestrial environments; they are a source of energy and nutrients, wildlife habitat, and, in streams, provide physical stability (Harmon and others 1986).

An ecosystem study on the South Fork of the Hoh River in Olympic National Park provides other illustrations of the relevance of the information in wilderness to managed ecosystems (Starkey and others 1982). The park area was selected because it had an ecosystem appropriate for the study, an undisturbed coastal valley, and park managers who strongly supported the project. The project was an intense, short-term interdisciplinary study ("pulse") that looked at relationships among geomorphic processes, landforms, alluvial forests, aquatic (especially fish) productivity, and elk. The research included many components and yielded many individual findings, such as the importance of down logs as nurseries for regenerating trees in the coastal forests.

Observations of various aquatic habitats for total biologic and fish productivity, including factors involved in habitat creation and maintenance, provided significant information applicable to managed landscapes outside wilderness areas (Starkey and others 1982). Major forest influences on fluvial processes and landforms were evident in the South Fork. Bank cutting on the higher terraces produced accumulations of woody debris and formation of river bars downstream. Particularly notable were occasional accumulations of woody debris that blocked channel segments. This process resulted in formation of off-channel habitat, one of four major aquatic habitats in the South Fork; the other three are main channel, valley-wall tributary, and terrace tributary habitats. The off-channel habitat was isolated from the turbulent and sediment-filled water of the main channel and provided aquatic organisms with clean, quiet water, good protective cover, and rich food sources. Off-channel habitat was overwhelmingly important in fish production and also functioned as a biological hotspot for the drainage system as a whole and as a refuge for main-channel organisms. Management prescriptions and State regulations for commercial forest lands outside Olympic National Park had concerned primarily main channels and largely ignored off-channel habitats. Perspectives were altered by this wilderness research, changes in attitude of critical importance in this region where anadromous fisheries and timber harvest are prominent. The South Fork study also provided a standard for sediment levels tolerable to salmonids.

There are other good examples of research in wilderness that are important in understanding basic ecological processes and developing management strategies. Long-term studies have been conducted of interactions between populations of gray wolf (*Canis lupus*) and their prey, particularly moose (*Alces alces*), in Isle Royale National Park (Michigan), the Boundary Waters Canoe Area (Minnesota), and Algonquin Provincial Park (Canada). These studies have drastically modified perspectives on the supposed balance between predator and prey populations and provided information necessary for managing an endangered species. Studies of fire history have been conducted in many wilderness areas, including the Boundary Waters Canoe Area and Selway-Bitterroot Wilderness (Montana), studies which would probably not otherwise have been possible. This research has provided essential information on natural fire regimes and helped alter attitudes from fire control to fire management, both inside and outside wilderness areas.

Hence, information from the wilderness, extracted through scientific research, has direct relevance to managed landscapes. It is also of value to the wilderness manager and builds the total information base for the wilderness area. Wilderness is also the source of as yet unasked questions—and their answers.

PROBLEMS IN EXTRACTING THE INFORMATION RESOURCE

Scientific research is the usual method by which we extract information from a source; unfortunately, we scientists and managers have made a poor start in extracting information from wilderness. Some positive examples are appearing for individual wilderness areas, but the general record of research use is abominable.

The low level at which the wilderness information resource is used is not because of unrecognized potential. The Wilderness Act (Sec. 4(b)) (The Wilderness Society 1984) gives equal weight to the scientific and recreational values of wilderness: "Wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use." Science in wilderness has been talked about for a long time; an early wilderness conference dealt exclusively with the scientific values of wilderness (Sierra Club 1964). But the promise remains mostly talk.

Perhaps part of the problem has been the lack of a strong advocate for the science resource. Much of the Wilderness constituency does not understand the importance of the opportunities. The Wilderness Act Handbook (The Wilderness Society 1984) has extensive material on Congressional clarifications of the original intent of the Wilderness Act and is useful in examining this issue. It is clear in the handbook that treatment of most resources—fish and wildlife, minerals, grazing, and so on—is either dealt with in the Act or has subsequently been clarified. All uses, that is, except for science. The use of the information resource has not been subject to further Congressional consideration. The reason is clear—the issue has not been raised; the scientific resource has no constituency.

Several issues or problems have deterred scientific use. These problems can be categorized as attitudinal, regulatory (mostly logistical), and conflicting use. Significant differences do exist among agencies, regions, and even individual wilderness areas in the intensity of these problems, just like the differences in the current level of scientific research. These differences are expected, given four agencies operating under four sets of regulations based on four laws (1965 Wilderness Act, Eastern Wilderness Act, Endangered American Wilderness Act, and Federal Land Policy and Management Act of 1976) (The Wilderness Society 1984). Agency differences clearly affect both the amount and type of research that goes on within wilderness areas (Butler and Roberts 1986).

Scientists themselves contribute to the attitudinal problems. They are often uninformed about regulations and unwilling to make necessary compromises to conform with wilderness values. Scientists can be arrogant and cryptic in their relations with managers and unappreciative of managers' problems. Some may feel that research gives them a license to do whatever they please. Scientists are, on the other hand, almost always short of the resources they need to carry on their research programs.

Managerial and user attitudes toward research in wilderness also are problems. These attitudes, which may include hostility and disinterest, apparently reflect a lack of appreciation of the potential value of scientific study. Some managers want only research that is clearly relevant to their immediate management problems. The Forest Service manual currently directs that if research can be done elsewhere, outside the wilderness, it should not be allowed within the wilderness; such direction (to do it elsewhere if possible) is not applied to any other use of wilderness which would otherwise conform with Congressional directives. New policy direction (approved but not yet published) is more positive; its objectives are to provide appropriate opportunity for scientific studies dependent on a wilderness environment and to encourage research in wilderness that preserves the wilderness character of the area.

Some attitudinal problems may result from poor education of managers on the importance of scientific use of wilderness and how research can benefit the preservation of wilderness in the long run.

Problems related to agency regulations (and their interpretation) include access, research methods, and instrumentation. Many wildernesses are rugged, and sampling sites may be remote. The long travel times may be a direct problem in processing chemical or other samples. A further complication may be the need for frequent sampling. Bulky or heavy equipment not suitable for ground transport by people or pack animals may be required to accomplish research objectives. Helicopter or other motorized access may be the only way to move such equipment or the way that has the least impact on wilderness ecosystems.

Research methods are another area of conflict. Although a lot of useful research can be accomplished with equipment no more complicated than a pad of paper, pencil, and measuring tape, much ecological research requires complex instrumentation. Some of this is electronic equipment that may, in turn, require a power source. Various kinds of temporary installations—instrument shelters, stream gauging stations, and exclosures—may be needed for specific research projects. Field markings, such as stakes for permanent plot boundaries, are often critical to ensure relocating study areas.

The third major problem is conflicting human activities. There are major differences among agencies in the seriousness of this problem. National Park Service wilderness areas are generally of higher value for ecological research than wilderness areas administered by other agencies because most conflicting human uses are absent.

Remember that naturalness is one of the chief reasons for the value of wilderness to science and society. But conflicting human activities drastically alter natural processes and are typically allowed in most wilderness tracts; such activities include grazing by domestic livestock, big game hunting, trapping, fishing, fire control, and recreational use. Hunting precludes studying the natural ecology and population biology of game animals. Hunters may also affect populations of nongame animals or even eliminate them from local areas as I had the misfortune to observe with hoary marmot (*Marmota caligata*) populations in a basin in the Goat Rocks Wilderness (Washington State). A major impact of fishing has been the introduction of fish into previously barren lakes, which has drastically altered the trophic structures. Recreational use differs widely in intensity, but its impact could be heavy and result in casual interference with plots or instruments.

Human activities also include the accidental introduction of exotic organisms, such as diseases and insects (for example, white pine blister rust, chestnut blight, gypsy moth, and balsam woolly aphid), which have drastically altered the natural ecosystem. Unfortunately, most of these impacts cannot be controlled or eliminated from wilderness ecosystems.

Scientific research can help us appreciate the substantive as well as the cosmetic changes that have occurred and continue to occur in wilderness tracts. Our general failure to appreciate how unnatural, however attractive, many of our wildernesses are frequently frustrates me. I think that wilderness management has focused on cosmetic rather than substantive issues. Wilderness users and managers are more concerned with the appearance of naturalness than with understanding and maintaining natural processes. This may be one reason why scientific use is tightly constrained; it is an activity that often has high visibility and lacks advocates, while other uses that subtly but seriously alter natural processes are allowed. Compromises necessary to pass the Wilderness Act in Congress guaranteed continued grazing and mining in National Forest wilderness, for example. Scientific investigation is not the major threat to natural processes in wilderness ecosystems; it does seem to be an easy target compared to greater threats, however.

INCREASING SCIENTIFIC USE OF WILDERNESS

What can be done to expand scientific use of wilderness? This assumes that there is general agreement on the desirability of greater efforts to extract the information resource of wilderness. Legislative clarification is one possibility, if there is really a question about the intent of Congress regarding scientific use of wilderness. There is always the chance of unexpected and undesirable outcomes from Congressional encounters, however, and the probability of not actually clearing away much fog. In fact, the issue may be one of agency attitudes and regulations and their interpretation rather than a legislative issue.

Zoning of wilderness is a possible way to deal with some conflicting uses. For example, segments of or even entire wilderness areas that have outstanding scientific values could be identified. Within such areas, recreational or other conflicting uses could be constrained, natural processes emphasized, and greater latitude in scientific methodology tolerated. Zoning is already practiced in many wildernesses, as shown by control of pack stock and allowance of semipermanent camps in some locations. The proposal for zoning is not a suggestion to be applied wholesale to the entire wilderness system but, rather, for limited areas identified after extended investigation.

Education is almost certainly an important step in improving scientific use of wilderness. Modified attitudes among managers, scientists, and users may be in order, and greater communication between these three groups is clearly necessary. I believe the importance of scientific study in wilderness to both the wilderness itself and society is not appreciated. The variety of research and equipment that might be used and potential impacts on natural processes and on appearances need to be clarified and discussed. The issue of cosmetic versus substantive impacts also needs to be aired.

Managers need to actively solicit and facilitate research, and not just that data relevant to their current problems. Some existing programs, such as the National Park Service's contribution to the National Acid Precipitation Program, provide excellent examples of how basic research can generate information of direct interest to wilderness managers. These programs also provide examples of cooperation between scientists and managers to carry out such research without significantly damaging wilderness values.

Scientists, for their part, have several obligations. They will have to accept logistical and methodological constraints on their research so that it fits within the wilderness ethic. Scientists need to develop improved techniques to conform with wilderness goals, such as methods involving minimum impact. Greater efforts to work with and inform managers are necessary. Colleagues and funding agencies, such as the National Science Foundation, need to be educated on the critical role of wilderness areas in ecological science.

Substantial involvement of scientists in wilderness planning could significantly expand the role of research and science in wilderness. Scientists could assist in identifying research needs and potential, including resources of special scientific interest, within specific wildernesses. In the process, they would become better informed of the opportunities and constraints and develop an effective dialog with managers and other user groups. Mutual education and promotion of the scientific use of wilderness would be an expected result of such involvement.

CONCLUSIONS

I have not emphasized research for the management of wilderness, although it is obviously critical. Such research is in short supply, but it at least has some constituency. I believe that we need to significantly expand appreciation of the importance of wilderness science, of knowledge from natural ecosystems to the World at large. There has been a lot of rhetoric, but the positive evidence of its value is now accumulating. Managers, scientists, and users need to work together to develop the mandates, procedures, and funds to use these most important outdoor laboratories.

ACKNOWLEDGMENTS

I am grateful to those who commented during the preparation and review of this manuscript. They greatly assisted in making the paper a more positive and constructive contribution to the topic of wilderness research than the original presentation. They include R. F. Buscher, W. K. Ferrell, G. E. Haas, M. L. Heinselman, J. C. Hendee, R. C. Lucas, and G. H. Stankey.

REFERENCES

Butler, Lisa Mathis; Roberts, Rebecca S. Use of wilderness areas for research. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 398-405.

Franklin, Jerry F. Wilderness for baseline ecosystem studies. In: Proceedings, XVII IUFRO World Congress Div. 1. Tsukuba City, Japan: Japanese Forest Experiment Station; 1981: 37-48.

Franklin, Jerry F.; Cromack, Kermit, Jr.; Denison, William; [and others]. Ecological characteristics of old-growth Douglas-fir forests. General Technical Report PNW-181. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 48 p.

Harmon, M. E.; Franklin, J. F.; Swanson, F. J.; [and others]. Ecology of coarse woody debris in temperate ecosystems. In: Advances in ecological research. Vol. 15. London, New York: Academic Press; 1986: 133-302.

Maser, C.; Trappe, J. M., eds. The seen and unseen world of the fallen log. General Technical Report PNW-164. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1984. 56 p.

Sierra Club. The meaning of wilderness to science. San Francisco: Sierra Club; 1964. 164 p.

Starkey, E. E.; Franklin, J. F.; Matthews, J. W., eds. Ecological research in National Parks of the Pacific Northwest. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1982. 142 p.

The Wilderness Society. The Wilderness Act handbook. Washington, DC: The Wilderness Society; 1984. 64 p.

AUTHOR

Jerry F. Franklin
Chief Plant Ecologist
Pacific Northwest Research Station
Forestry Sciences Laboratory
Corvallis, OR 97331

SCIENTIFIC ISSUES IN THE DEFINITION OF WILDERNESS

George H. Stankey

ABSTRACT

This paper examines some of the important scientific issues underlying wilderness protection. Specific scientific criteria to define wilderness are identified, and the extent to which these criteria are incorporated within the process of preserving wilderness in the United States is discussed. Needed actions to highlight and protect scientific values in wilderness are discussed.

INTRODUCTION

A dominant theme in wilderness literature concerns the scientific values such areas hold. The purpose of this paper is to explore some of the issues that underlie the scientific values of wilderness, to identify some of the specific scientific criteria that contribute to the definition of wilderness, and to consider how adequately the U.S. Wilderness Act (Public Law 88-577) meets the concerns of scientists. Some concluding remarks discuss how these scientific concerns might be better met.

Wilderness is a term plagued by an enormous range of interpretation. Even in the United States, where it has acquired legal status, there remains considerable confusion; the term is often used to describe any area outside a developed setting. This confusion likely has its roots in the fact that wilderness in our culture is perceived as an antonym of civilization and, consequently, the concept is often used to describe any area not possessing the general qualities of civilization (Nash 1982).

For the purposes of this paper, wilderness describes those areas where management objectives feature protection of the natural processes that have shaped the physical-biological character of the setting. Mechanized access is prohibited or greatly restricted as are resource exploitation activities. Recreation is a legitimate use, yet subordinate to the goal of environmental preservation. Such areas provide a variety of values to society, including scientific values.

Calls for the protection of wilderness have been driven by many different concerns, including the desire to protect areas that provide primitive recreation opportunities; the need for protection of scenic resources; moral/ethical concerns, including protection of future options; concerns with the efficient use of resources; protection of the environment, particularly watershed and wildlife; and concern with the protection of important scientific values. It is these latter values that we are especially concerned with here; in the next section of this paper I want to discuss in some detail those specific characteristics of wilderness settings critical to science.

WILDERNESS AND SCIENCE

My focus here is on wilderness as a setting for research on the natural environment. Certainly wilderness is an important setting for human activity and many important research issues can address such use (such as how people organize and cope in natural settings, what benefits accrue to society from exposure to the natural environment). Many of these issues, however, could be investigated effectively in areas other than those where the setting is substantially unmodified by human activity. However, research on the roles of the structural components of unmodified ecosystems or the genetic diversity within such ecosystems is dependent on the availability of areas where human activity and impacts are minimal. Thus, research priorities in wilderness areas should focus on ecologically, not socially, oriented issues.

Although it is not my intention to argue the relative merits of basic versus applied research in this paper, it does need to be pointed out that much of the concern for a heightened role for research in wilderness focuses on the need for more basic investigation. This in no way denies the value of applied studies. If our pursuit of scientific understanding in wilderness, however, is limited to the acquisition of knowledge to mitigate or prevent problems, the frontiers of learning will be severely constrained. In fact, they would be effectively limited to those matters judged in need of immediate solution by managers. Development of a basic understanding of long-term processes and dynamics whose implications for management might become apparent only in the very long term would be forgone.

Many specific scientific values can be noted; most fall into one of the following three categories:

First, wilderness is valued as a setting that provides a baseline of the conditions in the natural environment that have evolved outside human influence. Leopold (1941) argued for the preservation of wilderness as a "land laboratory" where a base-datum of normality would be available for comparison with areas modified by human use and occupance. Few areas remain where the landscape is substantially unaltered and uninfluenced, making those areas all the more valuable from a scientific perspective (Cain 1960).

Second, wilderness provides a setting where the nature, role, and function of the various components and processes of the wilderness can be investigated, again away from sources of disturbance. Franklin's 1982 studies of the temperate coniferous forests of northwestern North America provided important insights into the functioning of the various structural components of these forests. Such insights can lead to improved prescriptions for the management of areas outside wilderness. They also help reveal critical components that may be lost when areas are disturbed. For instance, Darling (1960) cited how the loss of sensitive pill millipede in eastern woodlands during timber harvest disrupts the conversion cycle in which detritus is converted to soil. Even when tree growth recurs, an essential element in the ecosystem has been lost, reducing the site's long-term productivity. Understanding these complex relationships and functions is contingent upon there being places where these processes are undisturbed; wilderness is one area where this is the case.

Finally, science is concerned with the long-term preservation of wilderness because there simply has not been adequate time or effort to discover all the values such areas possess. I am reminded of Leopold's assertion that such areas possess the answers to questions we have not yet learned to ask. The widespread loss of species, particularly in the tropical rain forests, carries with it an unknown impact on science. Myers (1979) estimated that, during much of the present century, about one known species per year has become extinct, but that because of the lack of knowledge about how many species even exist, the overall extinction rate among all species, whether known to science or not, could be at least 1,000 and conceivably as high as 40,000 per year. This latter rate would mean the loss of at least 1 million species by the end of the century. I can only speculate as to the benefits being lost to humankind, but it is likely that significant economic and social benefits are involved. Certainly one major concern is with the shrinking genetic base as human activity drives ecosystems to simpler, more spatially concentrated forms. The loss of gene pools in which ancestral diversity exists could mean that our ability to develop, for example, new variants of plant species would be greatly reduced (Cutler 1980; Myers 1979).

Wild lands, places where natural forces and their effects still predominate, thus possess great scientific value. But beyond this general observation, we need to pursue two important issues. First, what are the specific characteristics of wilderness settings that maximize their scientific value? And second, to what extent are these criteria explicitly addressed in the U.S. Wilderness Act? I turn to the first of these questions next.

SCIENTIFIC CONSIDERATIONS FOR SELECTION OF WILDERNESS

What specific wilderness considerations are important to science? It seems to me that four broad classes of scientific concerns can be defined. First, there are the specific characteristics of the area, including size, shape, boundary location, flora and faunal composition, representativeness, and successional stage. Second, there are concerns with permitted uses within the area, including recreation, exploitative activities, preexisting impacts, and fire exclusion. Third, the long-term security of the area, including its legal status with regard to permanent protection, as well as its susceptibility to impacts such as acid deposition from within as well as outside the area is a concern. Finally, there is a concern with the extent to which scientific values are recognized explicitly in the area's management policies, including the development of specific guidelines for scientific investigations.

Characteristics of the Area

An obvious and primary concern of scientists in the allocation of wilderness is the character of the area. Many specific concerns are involved. The appropriate size for nature reserves, for example, has long been a concern of scientists. It is important that reserves offer adequate protection of the area's environmental assemblage and ecological processes active in the area. Because most reserves are surrounded by areas under varying levels of development and modification, size offers a buffer to outside influences that might alter the natural character and processes within.

In addition to its role in protecting an area's ecological integrity, size is important in the maintenance of species diversity. Studies in island biogeography support the idea that, in general, larger reserves support a greater range of species (Diamond 1975; Simberloff and Abele 1976). Although the results of island studies have been criticized as to their applicability to continental situations (see Slatyer 1975), there remains general agreement that reserves need to possess a size adequate to protect the resources they contain.

What constitutes adequate size remains a complex issue. Research under way in Brazil under the auspices of the World Wildlife Fund and Brazil's National Institute for Amazon Research is designed to provide better understanding of the consequences of alternative reserve size on an area's capacity to preserve the principal characteristics of its ecosystem and to maintain biological integrity (Lewin 1984). Such studies could greatly aid both managers and scientists in determining what size wilderness reserves should be to achieve the purposes underlying their establishment.

Closely related to concerns with size are questions related to an area's shape and the location of its boundaries. Generally, compact shapes are preferred over distended forms, although for some species such as birds, connected lineal forms might be important in providing continuous habitat (Diamond 1975). Boundaries should incorporate all the critical components of the ecosystem; ideally, this should include topographically discrete units. If boundaries do not include all these critical components, the area's value for science is reduced; the effectiveness of the reserve is diminished by the lack of control over those areas outside the boundary (Polunin and Eidsvik 1979).

Perhaps one of the overriding concerns of scientists is the quality of the reserve's natural conditions. As Bourliere (1962) noted, parks and reserves (and we can include wilderness here) are the real laboratory of ecology. The naturalness of the communities, the diversity represented within them, and the representativeness of the system(s) are all major concerns.

Protection of a representative range of diverse ecosystems has been a long-term concern of many scientists. Although it is clear that wilderness classification cannot be expected to preserve the entire range desired, such reserves are an important component of any overall conservation program as it is in such areas that the undisturbed status of these systems can best be studied.

Many of the world's wilderness reserves owe their status not to unique biological characteristics, but rather to their scenic values or to the fact that they were available and had limited potential for other uses (Costin and Mosley 1969). Many wildernesses owe their protection not to any scientific criteria, but rather to the presence of strong public and political pressure (a perfectly legitimate rationale, I might add). Although subject to many criticisms, one important aspect of the U.S. Department of Agriculture, Forest Service's RARE II project was the effort to review and recommend, in a systematic fashion, areas for wilderness designation that possess biophysical characteristics currently not represented within the National Wilderness Preservation System (NWPS).

Biophysical representativeness in wilderness or similar reserves, however, is generally considered poor. At the international level, the Biosphere Reserve program is intended to conserve a representative sample of ecosystems and ecological zones (IUCN 1979). Worldwide, however, less than 250 such areas have been set aside (IUCN 1982). Of the 193 biogeographic provinces in the world (Udvardy 1975), 16 have no protection at all, and 33 are protected in fewer than five areas covering an area of less than 100 000 ha (Harrison and others 1984). In the United States, only about 100 of the 233 distinct ecosystems in the country (following the Bailey-Kuchler method) are represented in the NWPS (Davis 1980; Kirby in press). Adding wilderness reserves under the management of State governments expands this coverage somewhat, but still leaves significant gaps in ecological coverage (Stankey 1984).

Diversity is also an important quality of wilderness reserves, both within areas as well as across a system of reserves. The loss of wild landscapes, coupled with the tendency toward ecosystem simplification in modified environments, is leading to a steep decline in biological diversity. As Wilson (1984) noted, "In our own brief lifetime . . . deep mines of biological diversity will have been dug out and carelessly discarded in the course of environmental exploitation, without our even knowing fully what they contained." The loss of diversity also means a loss of genetic variety, with its associated consequences for scientific and medical research as well as other sectors of our lives (Myers 1979; Prescott-Allen and Prescott-Allen 1982).

Uses Permitted in the Area

The ideal of wilderness generally implies an absence of modern, technological human activity. In reality, a variety of human activities persist in such areas. This includes activities consistent with the area's classification as wilderness (such as low-density recreational activities) as well as preexisting uses whose continued pursuit is protected through law or other legal agreements (such as grazing and mining under the U.S. Wilderness Act or subsistence hunting and gathering in some African reserves).

Such uses and the impacts associated with them represent potential threats to the scientific integrity of wilderness. Two specific problems can arise. First, human use can alter the natural processes within the area through the introduction of exotics, the importation of nutrients, and the elimination of critical components of the ecosystem. Second, human activity, either accidentally or purposefully, can directly impact scientific investigations. We will return to this latter point in the next section.

Integrating scientific uses of wilderness with other permitted uses means compromise. It is important, however, to keep the impacts associated with these other uses in perspective. For example, although recreation is a major use of U.S. wilderness and possesses the capability of conflicting with various scientific pursuits, its highly concentrated nature often means that such conflicts are minimal. Cole (1981) found that in the Eagle Cap Wilderness in northeastern Oregon, only about 1.5 percent of the area had sustained impacts from recreation use, but long-term suppression of fire had resulted in subtle changes throughout the area. As a consequence, the primary impacts on the area, from a scientific perspective, stemmed not from current recreation use, but rather from policies constraining the use of fire. Similarly, the profound biotic impacts introduced along the Colorado River in Grand Canyon as a result of construction of Glen Canyon Dam far outweigh the significance of recreational impacts stemming from river runners, yet much of the concern with controlling impact is focused on the river's recreation use.

Although it would be desirable from the scientist's viewpoint if these other uses were not allowed, it is unlikely that sufficient political support could be garnered for the preservation of substantial tracts of land solely for scientific investigation. Although such strict preservation is possible for small tracts of land (research natural areas and other nature reserves), wilderness reserves offer much larger areas that provide more adequate ecosystem protection. The price paid for in size is the opening of the area to various other uses.

Long-term Security

A third element of concern to scientists (as well as to many other advocates) is the long-term security of the area's designation. The need for such assurances is recognized in IUCN's discussion of national parks; in such reserves, it is noted, "The highest competent authority of the country has taken steps to prevent or eliminate as soon as possible exploitation or occupation in the whole area and to enforce effectively the respect of ecological, geomorphological or aesthetic features which have led to its establishment" (IUCN 1982).

The issue of security involves two concerns. First, there is a concern with the permanence of the designation. If an area is established as wilderness, can we expect the protective designation to prevail in the future? Although any classification is subject to change, generally legal or statutory protection is preferable to administrative protection. In the United States, the press for a wilderness law was driven in large part by concerns with the vagaries of the existing administrative system of wilderness protection.

A second concern regarding long-term security involves the extent to which the area is protected from influences that can adversely impact its natural integrity from within as well as outside. Although careful boundary location can avoid or mitigate external threats, we must remember that boundaries are largely the artifacts of administrative convenience and permeable to a host of influences. Although the analogy is perhaps overused, it remains an unfortunate fact that wilderness reserves are islands in a sea of development and modification. Hence, a major concern, along with the natural qualities within an area, is the nature of activity surrounding an area. The presumption that the integrity of an area can be fully protected within its established boundaries is ecological folly. Whether the surrounding lands are managed as a buffer or whether they are managed so as to integrate the objectives of the wilderness reserve with those of the adjacent lands, it is critical that the context within which wilderness exists be taken into account (Machlis and Tichnell 1985).

Even the above precautions are not adequate to protect a wilderness reserve from all threats. Today, growing international concern with acid deposition highlights the interdependent nature of our environment. Such a threat jeopardizes many of the scientific values wilderness contains; inadequate baseline data regarding pH levels in pristine water courses also hampers the ability to fully assess the nature and rate of acid deposition on our environment.

Security is a major concern of scientists because much of the research that needs to be conducted is long range. The value of such projects, and their benefit to society, are dependent on the investigators being able to follow changes in the environment over extended periods with minimal outside influence. Disturbances could result in the loss of potential benefits that such long-term research would otherwise produce.

Guidelines for Scientific Research

A final concern deals with the existence of specific guidelines and criteria that recognize and promote research in wilderness. As noted earlier, protection of scientific values in wilderness areas has been a common concern. Beyond this general concern, however, there remain specific questions with regard to how these scientific values might be best protected.

Several issues seem important here. These include the development of guidelines for appropriate use by scientists. Because much of the research would be long term, careful field marking becomes critical so that sites can be accurately relocated (Franklin 1984). Certain scientific work will require the taking of samples such as wedges or cores for fire history dating. Because wildernesses are generally areas where evidence of human use is minimal, sampling needs to be done as sensitively and unobtrusively as possible. More specific attention needs to be given to the question of the nature of research activity to be permitted. I suggest that, in most cases, research be limited to observational studies as opposed to experimental work. Experimentation seems to involve activities that are contrary to the general concept of allowing natural processes full sway. Some research activities fall into a gray zone; for example, the reintroduction of fire into fire-dependent ecosystems where long-term suppression has greatly altered the character of the ecosystem, resulting in historically unnatural fuel accumulations.

One excellent example of an effort to develop the kinds of guidelines discussed here can be found in a publication of the Australian Academy of Science, entitled *Scientific Research in National Parks and Nature Reserves* (Australian Academy of Science 1980). This publication provides a discussion of the role of science in such areas, the distinctions and value of applied as well as basic research, and the responsibilities of both managers and scientists with regard to research projects. It also offers some useful suggestions for minimizing conflicts between scientists working on research projects in reserves and area managers and users. These include: being intimately acquainted with the laws and policies governing the area, maintaining careful control of all work, particularly that which might result in undesirable impacts on natural processes, and providing periodic feedback on results to area managers.

RESEARCH UNDER THE U.S. WILDERNESS ACT

It is useful, in this closing section, to review the extent to which the U.S. Wilderness Act satisfies the various criteria discussed above. Of course, in addition to the law, individual organizational policies have evolved and these policies further define the role research has taken. Jerry Franklin has commented on these in his paper (this proceedings).

The U.S. Wilderness Act clearly calls for the protection of an area's natural qualities. Such areas, the Act declares, involve ". . . undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural condition and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable." The Act also addresses the size issue, stating that a wilderness contain at least 5,000 acres of land or be ". . . of sufficient size as to make practicable its preservation and use in an unimpaired fashion." It is clear from the legislative debate that the elaborative clause here was intended to allow the addition of areas smaller than 5,000 acres (such as islands), not to require that areas encompass complete ecological units. Finally, the Act contains language indicating that such areas may also contain ". . . other features of scientific . . . value."

The U.S. Wilderness Act contains no specific provisions regarding the selection of either representative or unique biophysical areas. Nor does it contain language regarding appropriate boundary locations. And although it recognizes that wildernesses may contain scientific values, it provides no special language to encourage or facilitate scientific investigations.

Nonetheless, it seems clear that a major role for science was envisioned by the Wilderness Act. It notes that wilderness "shall be protected and managed so as to preserve its natural conditions . . ." and that each agency administering wilderness "shall be responsible for preserving the wilderness character of the area." The capacity to meet these requirements rests substantially on the possession of an information base that allows managers to enact appropriate policies. It is from scientific investigation that much, though not all, of this knowledge derives (Leopold 1969).

Organizational response to the need for acquiring information of a scientific nature has varied. In a paper prepared for this proceedings, Butler and Roberts (1985) reported that research in the Forest Service and National Park Service varied in both extent and nature. In surveying research activity in 53 national forest wildernesses and 22 national park wildernesses, they report nearly 3.5 times as many research projects in the national park areas as in the national forest areas. Moreover, while nearly two-thirds of the research on the national forests was focused on recreation, only 2 percent in the national parks was. One-third of national park research focused on zoology, and nearly 20 percent each on botany and the earth sciences. The authors attribute the differences to a variety of factors, but in particular note the strong Forest Service concern with minimizing even research impacts and encouraging research outside wilderness.

Forest Service wilderness policy regarding research is strongly oriented toward applied studies. For example, policy noted in Forest Service Manual 2324.41 is "to conduct research to meet the needs of the act." A critical issue here is who defines "needs" and by what criteria. It goes on to state that policy with regard to research is to identify needed research in wilderness management plans, ensure that wilderness is essential to the request (that similar opportunities outside wilderness do not exist), and to mitigate conflicts to the extent feasible. Motorized or mechanized equipment is prohibited unless the research cannot be done another way. The recent request of the Environmental Protection Agency for permission to use helicopters during sampling of acid deposition in wilderness lakes in the West is an example of a negotiated arrangement where mechanized access is allowed. (The agreement permits mechanized access only when completion of certain chemical analyses of samples could not be achieved within critical time frames using foot or horse travel.)

The role of science and scientific investigations in wilderness is a controversial one. Science can be seen as one of the many interests clamoring for opportunities to further its aims. At one extreme we find the view that "research is a vested interest . . . although the . . . research worker may be altruistic and high-minded, he is funded and not invisible. Research workers . . . are rarely conscious of their own social, economic and environmental impact" (cited in Australian Academy of Science 1980). On the other hand, Franklin (1984) observed: "[we] do not propose scientific license in the use of reserves . . . or use of conspicuous markings in recreationally sensitive areas."

What seems to be needed is a clearer understanding of the critical scientific role that wilderness plays. Scientists must take greater initiative to underscore how wilderness reserves benefit society as a source of knowledge. At stake here may be the very success of maintaining and expanding our wilderness system. Over the past several years, for example, recreational use of wilderness has begun to stabilize, and when one examines the demographic structure of our society, it is likely this trend will continue. With it we can expect pressures to retard the growth of the wilderness system and possibly even to declassify some areas on the grounds that demand does not warrant so much area being classified as wilderness (the National Wilderness Preservation System presently contains about 89.5 million acres). Implicit in such a perspective is the view that the supply of wilderness should be tied directly to the recreational demands placed upon it. If this view prevails, however, it would mean the irreversible loss of many key wilderness settings. It seems important in response to such a view that we better define the full range of benefits that accrue to society from a program of wilderness preservation. Key among these are the scientific values such areas possess. In fact, a strong argument can be made that improved scientific utilization of wilderness represents a major way of conveying the benefits of wilderness to a broader sector of society than just recreation users.

Also, it seems clear that if science does not take a more active, even aggressive, role in asserting its interest in wilderness, it might well find its role relegated even further down the list of priorities. As Franklin (1984) has noted, "The scientific community must begin to put up or shut up; if we do not use our scientific reserves we will almost certainly lose them." The situation does not appear to be improving. Over 20 years ago, Cain (1960) remarked, "Many of us are caught, by stating that wilderness must be protected because of its value for scientific research, in an apparently untenable position . . . unable to point to any significant research already performed in the wilderness tract under question."

SOME NEEDED STEPS

Although America's large wildernesses hold great appeal for scientific inquiry, we must also recognize that such areas are not just large nature reserves or natural areas. They are wildernesses, with a particular meaning and purpose ascribed to them through the legal process. Scientists, along with other interest groups, must abide by these guidelines. Yet there remains the persuasive argument that science and scientific inquiry offer an important way of justifying the significant investment that society has made in the wilderness system. The principal gain is in acquiring a better understanding of how the natural world operates. Whether this translates into specific guidelines on how to manage these areas or simply represents an addition to the store of human knowledge, perhaps but not necessarily of benefit at some future time, does not seem to be a critical concern.

Several steps seem called for to capitalize on the scientific opportunities offered in wilderness. First, scientists must do a better job of conveying to citizens, politicians, and policy makers the significant scientific values contained in wilderness and the critical need to explore these values in depth. Care needs to be taken to develop realistic expectations; not all scientific discoveries will lead to direct benefits to society. The nature of scientific inquiry, however, is such that there must be latitude to pursue avenues of investigation free of the necessity of always being able to demonstrate immediate utility. Yet there seems to be sufficient cause to presume that enough short-run benefits will, in fact, accrue to warrant the commitment of societal resources to underwrite the needed research effort. Scientists face a major selling job in achieving this goal and, although not a new point, it needs to be emphasized that science needs to bring the mystery and excitement that accompanies it to lay audiences. Doing so will likely have major returns; I am convinced there is a latent public interest in the secrets of the natural environment that requires a creative, sensitive approach. The fine, popular television series on BBC produced by David Attenborough confirms how well received science can be.

Second, for science to better highlight the opportunities in wilderness, a more encouraging environment for research activity must be fostered. Although science must ensure that its activities do not jeopardize the processes and qualities that give wilderness its unique value, the potential contributions to society that will result from improved scientific understanding of these areas and the processes that shape them seem to warrant a broader and more flexible role than presently exists.

To address many of the concerns that likely underlie the fairly restrictive approach to research activities in wilderness, it would seem useful to establish a set of guidelines and principles to clarify what constitutes appropriate wilderness research activity. As suggested earlier, such a document should address issues such as sampling, the location of research activity, relationships between managers and researchers, and experimentation. The aforementioned publication *Scientific Research in National Parks and Nature Reserves* by the Australian Academy of Science is an excellent example of such a document. Basically, such a publication would establish a code of conduct for the scientific use of wilderness by codifying an agreed-upon set of norms for the definition, conduct, and dissemination of knowledge. It would provide the public, area managers, and scientists with clearly defined expectations about scientific activity in wilderness and would serve to highlight the importance of such work.

Finally, because it is difficult to accurately gauge either the amount or scope of current scientific work in wilderness, it is correspondingly difficult to build adequately a case for its existing, let alone potential, value. Some well-defined central repository of wilderness-based research is needed, a central clearinghouse that documents the location, nature, and scope of research activity. Such a location would offer those concerned with communicating the scientific values of wilderness an easily accessed source of information, either with site-specific data or with results from which they might be able to extrapolate to their situation (or get in contact with scientists who could assist them in doing so). And it would provide other researchers with an improved ability to identify research needs and opportunities for replicative research. Also, it would serve to better integrate studies from differing disciplinary perspectives. A good example would be the Sierra Club publication *Research Projects in the Sierra Nevada, 1970-1973* (Stanley 1974) that identified all the research undertaken in that area irrespective of disciplinary focus or organizational sponsorship.

In summary, an increased effort to document the critical scientific values contained in wilderness and to build a persuasive argument for ready, responsible, scientific access to these values is called for. Although there might remain some areas of conflict between the interests of science and those of the general public in wilderness, there is a great opportunity for the scientific community to capitalize on the significant public interest in, and support for, wilderness. Only in this way can we more nearly achieve the objective of securing "for the American people of present and future generations the benefits of an enduring resource of wilderness."

REFERENCES

Australian Academy of Science. Scientific research in national parks and nature reserves. Canberra: Australian Academy of Science; 1980. 51 p.

Batisse, Michel. The biosphere reserve: a tool for environmental conservation and management. Environmental Conservation. 9(2): 101-111; 1982.

Bourliere, F. Science and parks in the tropics. In: Adams, Alexander B., ed. First world conference on national parks; 1962 June 30-July 7; Seattle, WA. Washington, DC: U.S. Department of the Interior, National Park Service; 1962: 63-68.

Butler, Lisa Mathis; Roberts, Rebecca S. Use of wilderness areas for research. Norman, OK: Department of Geography, University of Oklahoma; 1985. 21 p.

Cain, Stanley A. Ecological islands as natural laboratories. In: Brower, David, ed. The meaning of wilderness to science. San Francisco, CA: Sierra Club; 1960: 18-31.

Cole, David N. Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness, Oregon: some management implications. Biological Conservation. 20(4): 247-270; 1981.

Costin, A. B.; Mosley, J. G. Conservation and recreation in arid Australia. In: Slatyer, R. O.; Perry, R. A., eds. Arid lands of Australia. Canberra: Australian National University Press; 1969: 158-168.

Cutler, M. Rupert. Wilderness decisions: values and challenges to science. Journal of Forestry. 78(2): 74-77; 1980.

Darling, Frank Fraser. Wilderness, science, and human ecology. In: Brower, David, ed. The meaning of wilderness to science. San Francisco, CA: Sierra Club; 1960: 95-106.

Davis, G. D. The case for wilderness diversity. American Forests. 86: 24-27, 60-63; 1980.

Diamond, J. M. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biological Conservation. 7: 129-146; 1975.

Franklin, Jerry F. Ecosystem studies in the Hoh River drainage, Olympic National Park. In: Starkey, Edward E.; Franklin, Jerry F.; Matthews, Jean W., technical coordinators. Ecological research in national parks of the Pacific Northwest; 1979 November; San Francisco, CA. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1982: 1-8.

Franklin, Jerry F. Keynote comments: prophylaxes for our research natural area system. In: Johnson, Janet L.; Franklin, Jerry F.; Krebill, Richard G., coordinators. Research natural areas: baseline monitoring and management: Proceedings of a symposium; 1984 March 21; Missoula, MT. General Technical Report INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984: 1-4.

Harrison, Jeremy; Miller, Kenton; McNeely, Jeffrey. The world coverage of protected areas: development goals and environmental needs. In: McNeely, Jeffrey A.; Miller, Kenton R., eds. National parks, conservation, and development: Proceedings of the world congress on national parks; 1982 October 11-22; Bali, Indonesia. Washington, DC: Smithsonian Institution Press; 1984: 24-33.

IUCN. The biosphere reserve and its relationship to other protected areas. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources; 1979. 19 p.

IUCN. 1982 United Nations list of national parks and protected areas. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources; 1982. 155 p.

Kirby, Peter C. Why have wilderness? In: Wilderness and natural areas in the East: a management challenge: Proceedings of the symposium; 1985 May 13-15; Nacogdoches, TX. Nacogdoches, TX: Stephen F. Austin State University; [in press].

Leopold, Aldo. Wilderness as a land laboratory. The Living Wilderness. 6: 3; 1941.

Leopold, Estella B. Ecological requirements of the Wilderness Act. In: McCloskey, Maxine E.; Gilligan, James P. Wilderness and the quality of life. San Francisco, CA: Sierra Club; 1969: 188-197.

Lewin, Roger. Parks: how big is big enough? Science. 225: 611-612; 1984.

Machlis, Gary E.; Tichnell, David L. The state of the world's parks: an international assessment for resource management, policy, and research. Boulder, CO: Westview Press; 1985. 147 p.

Myers, Norman. The sinking ark. New York: Pergamon Press; 1979. 307 p.

Nash, Roderick. Wilderness and the American mind. 3d ed. New Haven, CT: Yale University Press; 1982. 425 p.

Polunin, Nicholas; Eidsvik, Harold K. Ecological principles for the establishment of national parks and equivalent reserves. Environmental Conservation. 6(1): 21-26; 1979.

Prescott-Allen, Robert; Prescott-Allen, Christine. What's wildlife worth: economic contributions of wild plants and animals to developing countries. London: Earthscan; 1982. 92 p.

Simberloff, D. S.; Abele, L. G. Island biogeographic theory and conservation practice. Science. 197: 285-286; 1976.

Slatyer, R. O. Ecological reserves: size, structure and management. In: Fenner, Frank, ed. A national system of ecological reserves in Australia. Canberra: Australian Academy of Science; 1975: chapter 3.

Stankey, George H. Wilderness preservation activity at the state level: a national review. Natural Areas Journal. 4(4): 20-28; 1984.

Stanley, John. Research projects in the Sierra Nevada, 1970-1973. San Francisco, CA: Sierra Club; 1974. 32 p.

Udvardy, M. D. F. A classification of the biogeographical provinces of the world. IUCN Occasional Paper 18. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources; 1975: 1-48.

Wilson, E. Million-year histories: species diversity as an ethical goal. Wilderness. 48(165): 12-17; 1984.

AUTHOR

George H. Stankey
Research Social Scientist
Intermountain Research Station
Forest Service, U.S. Department of Agriculture
Missoula, MT 59807

WILDERNESS POLICY—AN INTERNATIONAL PERSPECTIVE

Harold K. Eidsvik

ABSTRACT

Legislated wilderness is a concept well developed and understood in only a few highly developed and economcally healthy countries. It is a concept hard to translate and more difficult to internationalize across cultures. A more appropriate way to popularize wilderness may be to widen its definition to include a zone management strategy rather than always separate legally designated units. Several established IUCN management zones exist that such a strategy could be used in.

INTRODUCTION

This paper explores wilderness from a global point of view, using the United States (U.S.) only as a point of reference. The key issue here is, where has the wilderness concept, in a legal sense, succeeded and where has it failed? There are many other aspects to wilderness. I have not, for example, focused on its emotional values or on its value as a rallying point for the protection of natural areas. With this proviso, I would like to make some observations on the current situation and on future opportunities.

Wilderness defined in legislation is a concept almost unique to the United States. It has gained some recognition in Australia, Canada, New Zealand, and South Africa. Of some 160 countries in the world, 155 have not acted on the wilderness message. Only in the U.S., Canada (three Provinces), and South Africa have wilderness areas been established under legislation. New Zealand is about to designate its first area. In other countries, wilderness is a zoning mechanism.

DEVELOPMENT OF THE WILDERNESS CONCEPT

Countries with legislated wilderness all share European roots. Early European use of the term "wilderness" referred to barren or uncultivated lands usually outside settled areas. However, even in 1681 Hampstead Heath in London was described as a "barren wilderness" in urgent need of cultivation (Thomas 1983, p. 27).

In 16th century England, current concepts of conservation were nonexistent. Society was utilitarian—"the artificial preservation of uncultivated hilltops would have seemed as absurd as the creation of sanctuaries for wild birds or animals which could not be eaten or hunted" (Thomas 1983, p. 14). Now in some ways, perhaps not much has changed. Much of human civilization remains virtually synonymous with the conquest of nature.

As 200 years drifted past, we found Americans, Canadians, Australians, and a few others all set to conquer the wilderness. By then wilderness had become the land at the edge of settlement—the frontier. Concepts of remoteness and ruggedness combined with a struggle for survival left little doubt that the enemy was wilderness.

About the middle of the 19th century, new perceptions of the frontier began to appear. Catlin and Muir, among the founding fathers of conservation, described it as a thing of beauty to be preserved. Soon, Yosemite (1864) and Yellowstone (1872) appeared on the scene. A new social concept was born in Yellowstone, a public park and pleasuring ground.

Across the Pacific in Australia, Hacking National Park was established. Now called Royal National Park, its centennial was celebrated in 1979. Today's concept of national parks was established. However, Sir Henry Parkes had this to say: "It is a wilderness and . . . years must elapse before it can be of any use" (Mosley 1978a, p. 27). It is clear that wilderness was not to be preserved for its intrinsic values. The utilitarian values assigned by Europeans to wilderness continued to be dominant.

Banff National Park was established as a "public pleasuring ground" in 1885. In New Zealand, Tongariro National Park followed in 1887. Turning to South Africa, we find more than a dozen large nature reserves established in the 1890's (IUCN 1984). All of these could, to a greater or lesser degree, be described as wilderness.

With one exception (Mexico), it appears that those countries that began their protected area systems prior to the turn of the century (IUCN 1984) are also the key figures in the wilderness movement. Another common attribute of these countries is that they are all countries with a sound economic base. It would appear that a "full belly" is a prerequisite to wilderness establishment.

Looking beyond the magnificent wilderness efforts of Robert Marshall, it strikes me that the next big push came in the 1950's.

In the early 1950's there was a real concern in the conservation community that what had been gained through the national parks movement was in real danger of being blacktopped. Burgeoning park visitation and the "Mission 66" program created a concern that no roadless areas would be left. In the U.S., one reaction to these concerns was the 1964 Wilderness Act that applied to national forests, national parks, and other Federal lands.

This need for additional protection had not hit the rest of the world, which was just beginning to get its first tier of protection established and was not subject to intensive park use. Traditional mechanisms of nature reserves, game sanctuaries, and national parks were gaining acceptance.

WILDERNESS AS A CULTURAL CONCEPT

In the developing world the concept of "wilderness" is an idea whose time has not arrived. Not only has its time not come, but there continues to be considerable confusion in the developing world about the meaning and values of wilderness. This subjective nature of wilderness was described by Nash (1967, p. 1):

> "Wilderness" has a deceptive correctness at first glance. . . . There is no specific material object that is wilderness. The term designates a quality . . . that produces a certain mood or feeling in a given individual and, as a consequence, may be assigned by that person to a specific place. Because of this subjectivity, a universally acceptable definition of wilderness is elusive. . . . Wilderness, in short, is so heavily freighted with meaning of a personal, symbolic, and changing kind as to resist easy definition.

I agree with Nash without difficulty. I also, however, agree with an Australian colleague who said, "We can't get anywhere unless we have sorted out our own terminology" (Smith 1978). In this respect, while there may be accepted definitions applied in the U.S., there does not appear to be an agreed-upon international terminology.

Wilderness is a value-loaded word. It is a word full of emotion on one hand and yet used with legal precision on the other. As an emotive word and a cultural concept, it is a powerful tool for conservation. However, we also use it in a legal sense—sometimes to define a zone in a park, a zone in a national forest, or a discrete new type of protected area. In this there is a danger of debasement. The original idea of large, primitive, remote areas remains important to the concept. When wilderness in the legal sense becomes 5,000, 3,000, or even 5 or 6 acres, it appears to me to have lost usefulness.

Wilderness has great value in the global cultural context. One need only read some of the early writing—whether Thoreau, Muir, Leopold, or Marshall or alternatively, the proceedings of the Third World Wilderness Congress—to gain a sense of its powerful impact on individuals. Yet, when we begin to use the term in a strict legal sense, it loses its impact. It lacks clarity; it lacks definition, and as a result has not been taken up as a conservation tool by many countries. It is this latter point that I am focusing on—if it is possible to focus on this wonderful, elusive thing called wilderness.

Having outlined some background, where do we in "the international conservation establishment," as defined by McCloskey (1984), go from here? He states that the International Union for Conservation of Nature and Natural Resources (IUCN) has a bias against wilderness, and that "the word 'wilderness' is almost regarded as a dirty word - a word that is better not mentioned" (McCloskey 1984, p. 1).

I don't admit to that bias, but I do agree with Mr. McCloskey when he says, "People kind of look askance at you if you want to use the word wilderness, as if - Americans have some peculiar penchant for that term" (McCloskey 1984). Frankly, I think this is true, but I see nothing wrong with it. Wilderness, as defined in the 1964 Wilderness Act, has served the U.S. people well, increasing protection in the national parks and creating new wilderness areas on national forests and BLM-administered lands. This does not necessarily mean it is a good or timely concept for the rest of the world. Nor does it mean that IUCN is opposed to it. On the contrary it is a good concept, in the right place, at the right time.

SOME GLOBAL PERSPECTIVES

From a global perspective there is a barrier in terminology. More fundamentally the language itself sometimes creates a barrier. My Spanish-speaking colleagues tell me there is no such word as "wilderness" in the Spanish language. On top of that, any translation is awkward. Similar problems arise in the French language. Thus, we are limited by vocabulary from easy communication about wilderness with much of the world.

Three World Wilderness Congresses (South Africa, Australia, and Scotland) have tried with only limited success to spread the wilderness message. The message remains diffuse. No one has defined acceptable criteria for concerns such as: how big should wilderness be; how remote should wilderness be; how pristine should wilderness be? I believe these are critical values or qualities; without guidelines, individuals are left to wrestle with biological values and then with anthropocentric perceptions, and finally with combinations of both. A quick global tour will expose the current situation and various conceptions relating to size, remoteness, and quality.

The Question of Size

North America.—Early Forest Service guidelines for primitive areas as wilderness were 230,000 acres; later this became 100,000 acres (ORRRC 1962). In 1964, the U.S. Wilderness Act brought this down to 5,000 acres; last year, Michigan legislation dropped it to 3,000 acres. In the early 1960's, Ontario wilderness areas were restricted to a maximum of 640 acres. Today a few wilderness islands are only 5 acres.

My personal bias suggests that we are not talking about wilderness in areas of 5,000 or 3,000 acres. These should be exceptions and not standards. We should use other terminology; perhaps roadless areas, perhaps nature sanctuaries, but surely not wilderness.

Australia.—A New South Wales study recommended a minimum area of 25 000 ha (62,000 acres), with a core area at least 10 km in width and a surrounding buffer zone of 25 000 ha (Mosley 1978b). This definition brings us back much closer to the earlier Forest Service definition of 100,000 acres.

New Zealand.—In New Zealand, wilderness areas must be large enough to take at least 2 days' foot travel to traverse (Govt. of N.Z. 1985). Depending on the terrain, one would anticipate that wilderness areas in New Zealand would exceed 50,000 acres.

The United Kingdom (A Unique Perspective).—Vice Admiral Sir Robert E. Brockman suggested a wilderness boundary based on the distance an average man could see if standing on a smooth sphere. His average man, 1.6 m tall, could see 5.6 km to the horizon. This would result in a circle approximately 30,000 acres in area (Brockman 1979).

The Question of Quality: How Pristine Should Wilderness Be?

A global perspective.—With nuclear submarines prowling under the Arctic icepack and tourist-laden jets crashing into Antarctic mountains, we may have lost our last wilderness. As Brower wrote in 1977, "There is no pure wilderness left. Radioactive fallout and the oozing of wastes have left no corner of the earth clean." This degree of purity could be described as one end of the continuum.

An Antarctic Perspective.—"There is unfortunately no true wilderness left. Global pollution has ensured that even Antarctica shows traces of industrial contamination - radioactive fallout and heavy metals have all been detected in Antarctica ecosystems" (Tierney and Johnstone 1978). Again, we are at one end of the continuum.

Two Views From the United Kingdom.—"There is no part of Britain that has not been grossly influenced by man" (Brockman 1979). However, the Admiral goes on to suggest that England's Dartmoor moorland offers a wilderness experience to urban man. No doubt it does, but I would question the authenticity of a wilderness that contains the following: prehistoric dwellings, stone monuments, sheep (necessary to clip the moors), a conifer forest plantation, a 231-meter TV tower, two small reservoirs and ancillary dams, a military presence involving the live firing of small arms, artillery, and mortars—separated in time and space from visitors. Add 150,000 children among 450,000 annual visitors to the wilderness. Take these away from the 8 million visitors to Dartmoor National Park and you have one man's wilderness and another man's zoo. The Admiral recognizes this and adds, "In a democracy how many coloured anoraks can you afford to see, before the wilderness ceases to be your wilderness?" (Brockman 1979, p. 207). This is, of course, the other end of the continuum.

Jamaican Perspective.—"In Jamaica, parks, recreation and wilderness are something of a luxury" (Young 1979).

South American Perspective.—We do not use the term "wilderness;" it has no meaning in Spanish (Dourojeanni 1984).

The Question of Remoteness

Australia.—As a beginning, ". . . one cannot have wilderness at the roadside or road's end because it is not remote from people, transport facilities, and other man-made aids. . . . The minimum degree of remoteness necessary for this wilderness seems to be that at least half a long day's travel is needed before one has even reached wilderness - say 10 km" (Smith 1978, p. 21).

Remoteness brings into play the question of buffer zones and options that would include or exclude them from wilderness. The U.S. position to begin at the roadside clearly differs from that of Australia and, as well, New Zealand.

SOME CONCLUSIONS

Having looked at a number of factors, we must decide whether our objective is to protect all roadless areas, no matter what size, as wilderness. Alternatively, is the objective to increase protection within existing protected areas? Or is the concept of setting aside discrete areas, 30 000 ha or 50,000 acres in size, remote and pristine, distant from the sights and sounds of man, still valid? If so, how can it be achieved?

It strikes me that if we focus on legislated wilderness as the only solution, we will continue to distort what appeared to be the clear objectives of large size, remoteness, and pristine qualities. We will end up with a word that means nothing, or means whatever you want it to mean. Simply put, the three essential requirements of wilderness are size, remoteness, and natural qualities. We need a rededication to these functions.

THE FUTURE POTENTIAL

If there were no potential wilderness areas, it would be folly to go on from here. To check what potential exists, I reviewed the prepublication draft of the 1984 United Nations List of National Parks and Protected Areas (IUCN 1984). To keep the task manageable, I made a list of all protected areas over 500 000 ha. These are outlined in table 1.

Table 1.—Protected areas over 500 000 ha in size (K = 1 000 ha)

Size	No. of areas
+ 500 000 ha	69
1 000 K but < 2 000 K	41
+ 2 000 K but < 3 000 K	19
+ 3 000 K but < 4 000 K	3
+ 4 000 K but < 5 000 K	4
+ 5 000 K but < 6 000 K	3
+ 6 000 K but < 7 000 K	0
+ 7 000 K but < 8 000 K	1
+ 70 000 000 ha	1
	141

The 70 million-ha area is Greenland National Park. Other high potential areas include: Salonga in Zaire, Kluane-Wrangell/St. Elias (Canada-U.S.A.), Kakadu in Australia, Manu in Peru, and areas on Irian Jaya, Indonesia.

In reviewing future action, it is important to remember that many of the 141 areas are still wilderness-like and are included in the above figures as are some legislated areas. However, for some of the reasons enunciated earlier most countries have not seen a need to create legal wildernesses.

Even in a "quick and dirty" overview such as the above, it is evident that within the world's existing network of protected areas containing some 400 million ha (McNeely and Miller 1984), there is ample potential to increase protection by applying wilderness concepts.

As a secondary consideration, I reviewed the 1984 United Nations List of National Parks and Protected Areas for countries with more than 10 million ha of proected area, perhaps with the naive thought that these might be targets for further study. In addition, I noted 0 countries with more than 5 million ha of protected area:

Country	Size (ha)
United States	[1]80 000 000
Denmark (Greenland)	70 000 000
Australia	34 000 000
Canada	21 000 000
U.S.S.R.	14 000 000
Indonesia	12 000 000
Botswana	11 000 000
Brazil	11 000 000
Chile	11 000 000
Tanzania	10 000 000

---

[1] Includes designated wilderness.

A FUTURE APPROACH

I mentioned earlier that very few countries had taken he approach of legally designating wilderness. On the other hand, wilderness as a management zone within park management plans is gaining acceptance.

Zoning is a reflection of the 1962 Outdoor Recreation Resources Review Commission (ORRRC) studies, the Second World National Parks Congress, propagation of he concept through the activities of the International Seminar on National Parks and Equivalent Reserves, the fforts of IUCN's Commission on National Parks, and many other proponents of management plans for protected areas. Zoning as a management tool was one of the most significant products of the 1962 ORRRC studies—the concept should be reinforced in ORRRC II.

IUCN has established 10 categories of protected areas (IUCN 1978). These are listed in table 2. Each type of protected area requires a management plan and each plan incorporates several zones, one of which could be wilderness.

Wilderness as a zone could readily fit into protected area categories 2, 4, 8, 9, and 10. Such designation could be made in the management plan with a stipulation that change requires public consultation or revisions in legislation.

CONCLUSIONS

It is clear that the legal designation of wilderness has taken hold in developed countries with a long tradition of protected area management. As a zoning concept wilderness exists in many countries, including Australia, Canada, Dominica, Ethiopia, Indonesia, Kenya, Thailand, and the U.S.A.

It is also clear that in the United States the original concept of wilderness as large, pristine, remote areas was changed by the 1964 Wilderness Act. The minimum standard of 5,000 acres has slowed the blacktopping of America's national parks. The Act has resulted in very significant additions to the wilderness network of the Forest Service and other Federal agencies, but it has also obscured the original meaning of wilderness.

We should not fail to recognize that we need to reach political decision makers to create new protected areas.

Table 2.—IUCN categories of protected areas

Category	Brief explanation
1. Strict nature reserve	Basically for scientific purposes, no manipulation, highest degree of protection
2. National/State/Provincial park	Designation depends on legal authority, would contain several zones
3. Natural landmarks/monument	Classic examples of features, generally not total ecosystems
4. Managed nature reserve	Ecosystems manipulated to favor certain plant or animal species
5. Protected landscape	A mix of cultural and natural features—U.K. national parks, French regional parks
6. Resource reserve	A holding category pending more data to make allocation decisions
7. Anthropological reserve/ traditional land	A reserve to permit acculturation or not, based on tribal desires
8. Multiple-use area	Management practices similar to those of the Forest Service in the United States
9. Biosphere reserve	International designation, representative area
10. World heritage sites	International designation, unique area

To get action we need a broad constituency. In many countries this support for wilderness does not yet exist.

If wilderness is to be used as a management tool for increasing the degree of protection in existing protected areas, I believe this can be achieved through zoning. Finally, if extensive new wilderness areas are to be established in the less-developed countries, it is my view that the same objectives can be more readily achieved by linking the wilderness concept, through zoning, to one of the existing IUCN categories of protected areas.

An expanded preamble to the protected areas categories paper could greatly elaborate on the value of wilderness that we all recognize and hold dear.

REFERENCES

Brockman, R. Dartmoor and its wild country. In: Player, Ian, ed. Voices of the wilderness: Proceedings of the first world wilderness congress; 1977 October; Johannesburg, South Africa. Johannesburg, South Africa: Jonathon Ball Press; 1979: 207-212.

Brower, D. Wilderness, a universal concern—(the wildness within us). In: Mosley, G., ed. Australia's wilderness: conservation progress and plans: Proceedings of the first national wilderness conference; 1977 October 21-23; Canberra, Australia. Hawthorn, Australia: Australian Conservation Foundation; 1978: 14-18.

Dourojeanni, M. [Personal communication with author.] 1984 June. Gland, Switzerland.

Government of New Zealand. Wilderness policy. Wellington, New Zealand: Department of Lands and Survey; 1985. 4 p.

IUCN. Categories, objectives, and criteria for protected areas. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources; 1978. 26 p.

IUCN. Categories, objectives, and criteria for protected areas. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources; 1984. 167 p.

McCloskey, M. Wilderness and world conservation establishment. 1984. Remarks to the northwest wilderness conference; 1984 April 28; Seattle, WA. 1 p. unpublished.

McNeely, J. A.; Miller, K. R., eds. National parks, conservation and development: proceedings of the world national parks congress; 1982 October 11-22; Bali, Indonesia. Washington, DC: Smithsonian Institution Press; 1984. 825 p.

Mosley, G., ed. Australia's wilderness: conservation progress and plans: Proceedings of the first national wilderness conference; 1977 October 21-23; Canberra, Australia. Hawthorn, Australia: Australian Conservation Foundation; 1978a. 308 p.

Mosley, G. Conserving Australia's wilderness: introduction to methods of defining wilderness and the extent of wilderness in Australia. In: Mosley, G., ed. Australia's wilderness: conservation progress and plans: Proceedings of the first national wilderness conference; 1977 October 21-23; Canberra, Australia. Hawthorn, Australia: Australian Conservation Foundation; 1978b: 112-117.

Nash, R. Wilderness and the American mind. New Haven, CT: Yale University Press; 1967. 256 p.

ORRRC. Wilderness and recreation—a report on resources, values, and problems. Study Report No. 2. Washington, DC: Outdoor Recreation Resources Review Commission; 1962: 18-19.

Smith, P. A philosophy of wilderness conservation. In: Mosley, G., ed. Australia's wilderness: conservation progress and plans: Proceedings of the first national wilderness conference; 1977 October 21-23; Canberra, Australia. Hawthorn, Australia: Australian Conservation Foundation; 1978: 20-26.

Thomas, K. Man and the natural world: history of modern sensibility. New York: Panthenon Books; 1983. 410 p.

Tierney, T.; Johnstone, G. Conserving Australia's wilderness: Antarctica as wilderness. In: Mosley, G., ed. Australia's wilderness: conservation progress and plans: Proceedings of the first national wilderness conference; 1977 October 21-23; Canberra, Australia. Hawthorn, Australia: Australian Conservation Foundation; 1978: 118-126.

Young, B. Conservation, parks and wilderness aspects of the Jamaican scene. In: Player, Ian, ed. Voices of the wilderness: Proceedings of the first world wilderness congress; 1977 October; Johannesburg, South Africa. Johannesburg, South Africa: Jonathon Ball Press; 1979: 213-216.

AUTHOR

Harold K. Eidsvik
Chairman, IUCN Commission on
National Parks and Protected Areas
and Senior Policy Advisor, Parks Canada
Ottawa, ON K1V 7C6

RESEARCH NEEDS FOR WILDERNESS MANAGEMENT— AN UPDATE FROM THE NATIONAL WILDERNESS MANAGEMENT WORKSHOP

Edwin E. Krumpe and William J. McLaughlin

ABSTRACT

In 1983, participants at the National Wilderness Management Workshop focused attention on "taking care of what we've got" by identifying the critical issues that face wilderness management. Five broad categories of issues were: educating the public, education and training of managers, capacity and concentrated use, interagency coordination and consistency, and wilderness management practices. Of the 23 priority actions recommended to address these issues, 11 specifically require both basic and applied research. Specific suggestions for the role of research are offered for each of the 11 actions.

INTRODUCTION

It is particularly relevant that we gather to discuss wilderness research in light of recent events affecting wilderness management. Additions to the National Wilderness Preservation System have increased the total area permanently protected from 15 million acres in 1964 to 88.6 million acres in 1985. Numerous additions in the East have brought wilderness to the very back door of over two-thirds of our Nation's population. Reports on threats to the National Parks; the specter of acid rain; the threatened demise of our grizzly bear; and eminent development of mineral, fossil, and geothermal resources next door to our parks and wilderness areas have helped sensitize the public to the delicate nature of our wildlands.

In the 21 years since passage of the Wilderness Act, we have finally put to rest the myth that wilderness requires no management (for example, Lucas 1973). Rather, both the managing agencies and the public have come to realize that we may indeed risk "loving our wilderness areas to death" through overuse, trampling, crowding, and impingement on personal freedom. The basis of this realization has come from the recognition that the hallmark of wilderness is its NATURALNESS—a place where the earth and its community of life are untrammeled by man, where natural ecosystems and natural processes are allowed to prevail as they have from time immemorial. This is not a new idea. It was recognized by the early founders of the National Parks, by foresters such as Bob Marshall and Aldo Leopold, by the authors of the Wilderness Act, and by the millions of conservationists and citizens who have worked to establish and perpetuate the wilderness system we have today.

In fact, it was this growing recognition that wilderness needs protection and that all is not right with our wilderness that gave impetus to an earlier national conference such as this that focused on "taking care of what we've got." I refer to the National Wilderness Management Workshop hosted by the University of Idaho Wilderness Research Center in October of 1983 (Frome 1985).

MANAGEMENT CONFERENCE GOALS

The theme of that conference was not research, but rather the management of our existing wilderness preserves. Our goal was to focus attention on identifying the critical issues that face wilderness management. We had an outstanding array of speakers and participants, many of whom are here today. But the heart of the conference was a series of small, structured working groups in which all attendees worked together to identify the issues and assign priorities to them (Krumpe 1985). This was not an easy process, and the 38 working groups identified approximately 1,000 issues. Besides the breadth and scope of the issues, perhaps what was most revealing was how much remains to be learned about managing natural ecosystems in diverse settings. Anyone who had come expecting simple answers was most certainly disappointed. For in reality, more questions were raised than were answered.

In fact, this initial identification of issues led Forest Service Chief Max Peterson to coordinate with the directors of the National Park Service, the Bureau of Land Management, and the Fish and Wildlife Service in calling for development of an action program to address these issues. As many of you may know, a national steering committee was formed with representatives of outfitters and commercial recreation interests; public and private fish and wildlife organizations; citizen organizations active in recreation, conservation, and preservation; research and educational interests; along with the Federal agencies. The committee's task was to solicit broad public involvement in pulling together the ideas generated by the workshop participants into an action program. Wilderness Management—a Five-Year Action Program (1985) is the published report that identifies and defines issues facing wilderness management and recommends actions to be taken by managers, by conservation organizations, by interest groups, and by private citizens. The issues are broad and the recommended actions cover a wide range of activities, many of which will take years to accomplish. Once again, we may have raised more questions than we answered.

Thus, when Dr. Glenn Haas, who in the early stages of coordinating this conference, expressed some concern to me that another conference in 2 years' time from our workshop would be repetitious, I heartily assured him that it would not. If anything, the National Wilderness Management Workshop pointed out a glaring need for more information and research to address the complex issues facing the management of wilderness ecosystems. Likewise, the Symposium and Workshop on Wilderness Fire, held in Missoula 1 month after our workshop, revealed that much was yet to be learned through scientific research, as did the Symposium on Wilderness and Natural Areas in the East conducted in May in Nacogdoches, TX.

Let me hasten to add, I see this call for research not as a self-serving plea by scientists to sustain their livelihood. Rather, I see a growing awareness and realization that much more knowledge and information is desperately needed if we are to ensure that wilderness resources and values are to be maintained and perpetuated for future generations. The Five-Year Action Program was aimed at improving wilderness management through 23 comprehensive recommendations that cover all aspects of wilderness management. Within these there is a clarion call for scientific research and study. Let me review for you 11 of the 23 recommended actions that call for further research.

EDUCATING THE PUBLIC

Of the five broad categories of issues, educating the public was the first listed. Successful plans and programs for resource management are wholly dependent on public understanding and acceptance. So it is with wilderness: as popularity rises and visitors come from nearby and afar, public understanding is essential to achieve respect for the resource, restraint, and willingness to adhere to appropriate uses. Such public understanding in many cases provides the desirable alternative to imposition of regulations and restrictions.

The first recommended action was to examine existing wilderness education techniques and evaluate their effectiveness, being sure that wilderness education material defines the wilderness resource and its values. At the workshop and in the followup public comment, numerous people expressed a belief in the importance of education as a management technique, while at the same time raising the question of how effective these efforts really are. This is a fertile field for research with potential to have important impact on wilderness management. Are wilderness information and education materials reaching the right people? Do people listen to or read them? Do they understand or remember the messages? To what extent does the material actually contribute to improved behavior in the wilderness? What things work well and what do not work very well, and why? These are some of the many questions concerning educating the public that require research to find the answers.

EDUCATION AND TRAINING OF MANAGERS

Workshop participants and the public at large identified a critical need to continually provide managers with education opportunities, updated information, and inservice training to enhance their ability to sensitively manage wilderness. Although some good work is being done in this area, managers often have limited access to such training; the workshops and training sessions are sometimes sporadic and may lack continuity or depth of coverage. The recommended action to institute and revitalize comprehensive inservice training utilizing both agency and nonagency expertise has direct relevance for researchers. As the agenda for the National Wilderness Research Conference amply illustrates, our knowledge base is growing exponentially. It becomes an opportunity and an obligation for researchers to translate their findings into understandable facts and concepts for the education of wilderness managers. The agencies sponsoring your research need to plan and budget for this followup as a part of the research projects. Whether you are involved in basic research on some natural species or phenomenon, or are scientifically collecting management information, the call for technology transfer is critical for today's wilderness manager.

Another opportunity for research will develop as the education and training of managers improve. Managers are continually conducting field miniexperiments when they implement management practices. All too seldom do researchers apply the scientific method to help design and evaluate these management practices. As we translate our research from the jargon of journals and ivory towers into useful concepts and applications, managers will more readily seek our advice and assistance in applying and utilizing research to solve management problems.

CAPACITY AND CONCENTRATED USE

Clearly, a third major category of issues facing wilderness management that was identified at the workshop is the problem of capacity and concentrated use. Within many wilderness areas are signs of trampling; erosion; damaged trees, plants, and natural features; introduced species; user-built structures; crowded campsites; human waste and litter; and user conflicts, to name but a few problems. Indeed we are in danger of "loving wilderness to death." Yet where use is restricted, other problems are likely to arise, including impingement on personal freedom and the perceived loss of the wilderness experience. Nevertheless, for wilderness to be wild it must be sustained as a healthy ecosystem, and to be enjoyed as wild it must be free from overuse.

Virtually all four recommended actions concerning capacity and concentrated use call for involvement on the part of researchers. The first recommendation was to set specific wilderness management objectives, giving priority to alleviating areas of concentrated overuse and including "limits of acceptable change" or similar principles as integral components of wilderness management plans. The limits of acceptable change concept is an innovative and promising approach to address the problems of capacities and overuse (Stankey and others 1985). However, assistance is needed from the research community to identify the best indicators of wilderness resource conditions to monitor, to delineate the sampling and measurement techniques, to define the interrelatedness of the systems we are monitoring, and to determine avenues for meaningful public involvement.

The second recommendation was to test varied approaches to resource rehabilitation and alleviation of overuse, and report evaluations of those approaches. There is a burgeoning, almost grassroots, effort in parks and wilderness areas to rehabilitate the impacts of past overuse. Yet research into the most effective techniques, the most suitable species, the most effective propagation and reintroduction methods, and the effects of climatic and site conditions is still lacking (Cole and Schreiner 1981). Many managers are making valiant attempts, yet often they have little concrete guidance from scientists. This is an important area of investigation that demands further attention from researchers.

Not only do managers sometimes lack scientific information, they often find it difficult to locate and retrieve what does exist. Thus, the third recommendation was to establish a computer library (or bulletin board) of wilderness training; education programs; and management techniques, such as handling concentrated use, data collection, monitoring, and rehabilitation. It must be easily accessible to all agencies, researchers, and educators. We see computers not as a panacea, but rather call for their information processing capabilities to be put to work and made readily available to serve wilderness management.

The fourth recommendation was to conduct research and development to establish procedures to modify undesirable behavior with the least impact on the quality of the visitor's wilderness experience. Many workshop participants recognized that the biggest problem facing wilderness management was the first three letters—man. Education; information; permits; rationing; location of campsites, trails, and trailheads; and regulating method of travel, equipment, group size, and time and length of visit are a few of the procedures managers have at their disposal to affect behavior. Researchers and managers should work together to test and refine these and other methods to provide the best management tools. Clearly, the problems of capacity and concentrated use provide fertile grounds for research.

INTERAGENCY COORDINATION AND CONSISTENCY

Coordination and consistency within as well as among agencies managing wilderness were called for by the workshop participants and the public at large during the comment period. Recommendations to accomplish this were to continue to develop and improve interagency wilderness management training programs and to coordinate communication among agencies on wilderness management.

Wilderness research can play a role by cutting across jurisdictional lines. We should share and contribute to the training of managers, regardless of their agency affiliation. Perhaps researchers can fulfill the role of impartial purveyors of useful information and thus help bridge the gap between the management agencies to the betterment of the National Wilderness Preservation System.

WILDERNESS MANAGEMENT PRACTICES

The fifth and final category of management issues includes wilderness management practices. Wilderness by its very nature requires a different approach than lands managed for other purposes, or even specifically for recreation. The perpetuation of the wilderness resource and its natural ecological processes must come first. Wilderness management also requires attention to what is happening around its boundaries and often extensively beyond them as well.

Two actions were recommended that require the expertise and support of research. The first is to identify, monitor, and publicly report internal and external threats to wilderness values from whatever source, whether overuse, acid rain, other forms of degraded air quality, or visual or sound impairments. The public has a right and a need to know of conditions that may threaten the integrity of their wilderness resources. Impartial research and the public reporting of the same in the long run will produce a more concerned, informed, and broad-based public constituency that will benefit wilderness management everywhere.

A second recommendation was to manage indigenous plant and animal communities to sustain natural processes, assuring that levels of human use are compatible rather than detrimental, with emphasis on preserving endangered and threatened species, as required by law. Once again, the emphasis is to maintain and perpetuate natural processes, a task that demands continued and increased attention from research.

BASIC RESEARCH NEEDS

Let me conclude by emphasizing that our research must not be constrained just to management or applied research. There exists a pressing need for basic research if we are to understand the natural processes that we are mandated to perpetuate. Research on plant and animal species (including humans), on the effects of physical and geological processes, on cumulative effects, on the dynamics of natural change, and on the functioning of interrelated ecosystems is vital if we ever hope to learn to manage and preserve and perpetuate our wilderness resource.

My point should be clear by now. A host of issues confronts wilderness management, and solving many of these issues will require the attention and best work of researchers. The National Wilderness Management Workshop focused attention on the necessity of "taking care of what we've got." It also amply illustrated that we now have the need for this National Wilderness Research Conference to lead the way in "learning to preserve" the most priceless resource of all—wilderness.

REFERENCES

Cole, David N.; Schreiner, Edward G. S., compilers. Impacts of backcountry recreation: site management and rehabilitation—an annotated bibliography. General Technical Report INT-121. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 58 p.

Frome, Michael, ed. Issues in wilderness management. Boulder, CO: Westview Press; 1985. 252 p.

Krumpe, Edwin E. Moving to action. In: Frome, Michael, ed. Issues in wilderness management. Boulder, CO: Westview Press; 1985: 189-203.

Lucas, Robert C. Wilderness: a management framework. Journal of Soil and Water Conservation. 28(4): 150-154; 1973.

Stankey, George H.; Cole, David N.; Lucas, Robert C.; Petersen, Margaret E.; Frissell, Sidney S. The limits of acceptable change (LAC) system for wilderness planning. General Technical Report INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 37 p.

University of Idaho. Wilderness management—a five-year action program. Moscow, ID: University of Idaho Wilderness Research Center; 1985. 12 p.

AUTHORS

Edwin E. Krumpe
Associate Professor of Wildland
Recreation Management and Director,
Wilderness Research Center
University of Idaho
Moscow, ID 83843

William J. McLaughlin
Head, Department of
Wildland Research Management
University of Idaho
Moscow, ID 83843

A FRAMEWORK FOR WILDERNESS ASSESSMENT AND RESEARCH

H. Ken Cordell
Alan E. Watson

ABSTRACT

A panel of key scholars has provided guidance in formulating a detailed outline of the 1989 Renewable Resources Planning Act Assessment of Wilderness. This outline includes recreational and nonrecreational wilderness values and uses and considers a broad definition of the wilderness resource. Embedded within this outline are questions which serve to identify the data, analyses, and research needed to complete the RPA and future assessments. We conclude this paper with identification of six critical research missions. These missions pertain to benefits, vicarious values, resource evaluation, modeling, recreational capacity, use interactions, and management and policy relationships. Ongoing research is needed to address these issue-derived missions so that the information and methodology voids that exist now need not be barriers to improving future wilderness assessments.

INTRODUCTION

The 1974 Forest and Rangeland Renewable Resources Planning Act (RPA) requires comprehensive national assessments of the forest and range resource base in the United States at 10-year intervals. The last such RPA assessment was completed in 1979.

Wilderness is an important component of the resource base as it is studied in the RPA assessment. In planning the 1989 Assessment, the Forest Service is seeking to improve the data, methods, models, and body of knowledge applied to describing, analyzing, understanding, and predicting the resource supply and demand situation. For wilderness, improvement of data on the users and uses of wilderness, its values and benefits, condition of the wilderness resource, interactions with other resource uses, and projections of future conditions and demands are being given close attention. Unless otherwise stated, our reference to wilderness in this paper will be limited to areas in the National Wilderness Preservation System as well as areas in State and private systems. By this definition wilderness includes roadless areas designated as wilderness by the owner and managed to protect the area's natural attributes while prohibiting mechanized and extractive uses, except as covered by grandfather clauses.

To develop an approach to this wilderness assessment, a panel of key scholars in the wilderness field was organized under the guidance of the Forest Service's RPA Washington Office. This panel has helped us to outline the needed assessment report and to identify the key questions, data, and analyses needed to assess the demand for and supply of wilderness in the United States. This outline and its inclusive questions will guide the 1989 Assessment. With the panel's help, we have gone beyond the 1989 Assessment and have identified data, analyses, and research needed for future wilderness assessments and policy deliberations.

This paper serves as a starting point for a problem analysis and plan for wilderness assessments and related research. While it focuses on existing data, analyses, and state of knowledge, it also describes the additional information and research needed to improve future assessments.

A national assessment should comprehensively describe and analyze demands, supplies, and social, economic, and environmental relationships with wilderness resources in an unbiased and objective manner. Interpretations of the results should be guided by the data, methods, and expertise employed; more so than by political or personal concerns. The goal is to produce a highly credible and unbiased RPA Assessment. To do so we will seek continued involvement and review by key scientists from universities and agencies. These individuals can contribute the ideas, concepts, analytical methods and models, data, and interpretations needed for the 1989 RPA, as well as future assessments.

The structure of the next section of this paper generally follows the outline intended for organizing the data and analyses for all the resources addressed by the RPA Forest and Range Assessment. Under each outline element are listed the major technical questions thus far identified. Most of these questions go beyond the problem of lack of data. Known data bases pertaining to demand, supply, and management of wilderness have been identified and listed. There are sure to be other relevant questions and data bases that should be included. At this symposium we seek to learn, as we have learned from the May 1985 Eastern Wilderness Conference held in Nacogdoches, TX. Questions and data pertaining not only to the National Wilderness Preservation System, but also to roadless areas under study and areas designated as wilderness by States or private entities must be included.

PROPOSED FRAMEWORK FOR A NATIONAL ASSESSMENT OF WILDERNESS

Here we outline our concept of the data and analyses needed for a comprehensive assessment of wilderness. Equally involved in conceptualizing this outline were Dr. Glenn Haas, Associate Professor, Colorado State University, and Dr. John Hendee (then with the Forest Service), Dean, School of Forest, Wildlife and Range Sciences, University of Idaho. This concept will not necessarily coincide completely with the outline and approach that are finally adopted for the RPA Assessment.

Ours is certain to be somewhat more comprehensive than the final assessment for RPA, because it serves additional purposes. One of these purposes is to stimulate research that would lead to improvements in our abilities to assess the demand for and supply of wilderness. Embedded within the outline that follows are questions which, as yet, have not been satisfactorily answered. These questions will form the basis for a proposed research agenda in a later section. We request comment and suggestions to refine this agenda.

The RPA Assessment will treat the recreational aspects of wilderness in the outdoor recreation assessment volume, the water aspects of wilderness in the water volume, and other nonrecreational aspects in the other relevant RPA resource assessment volumes. A national colloquium will be held in September 1987 to highlight the state of the art pertaining to the nonrecreational uses and values of wilderness.

CONCEPTUAL OUTLINE

A. Introduction

1. History, major issues, and trends in wilderness allocation, management, research, and education
2. Organization of the wilderness analysis

(Comment: This section is proposed to include identification of current issues that should guide analysis and bring focus to relevant program implications. A principal source will be the listing of issue priorities generated at the National Wilderness Management Workshop, University of Idaho, October 1983.)

Q. Do systems or models exist to guide or form the basis for a national wilderness assessment, such as Limits of Acceptable Change or the Recreation Opportunity Spectrum?

Q. What are the critical current issues in wilderness management, protection, and allocation which should drive a national wilderness assessment?

Q. How localized (disaggregated) do demand and supply analyses for a nationwide assessment of wilderness need to be—for example, by area, region within a State, region within country, national?

Q. How does the concept of wilderness fit with other preservation concerns such as critical faunal and floral habitat and biological reserves?

Q. How does U.S. wilderness fit within the global context of wilderness?

B. Prospective Trends in Demand

Q. How can trends in uses, demands, and values of wilderness best be expressed, measured, and projected?

Q. What are the relationships, tradeoffs, and relative trends among recreational, educational, scientific, human developmental, environmental preservation, and ecosystem representation demands for wilderness?

1. Onsite Recreational Demand
   a. Trends in participation and percentage of population participating

      Q. What surrogate measures of wilderness demand can be identified and what limits of interpretation should be imposed?

      Q. How can trends in use of newly designated areas be estimated given that historic records do not exist?

      Q. Are users of wilderness areas changing and what is the proportion of new users?

      Q. What is the relationship between wilderness education programs and the level and type of use of wilderness?

      Q. What is the extent and character of recreational use of non-System wilderness and how is this changing?

   b. Projections of Participation Changes by Region

      Q. What are the relationships between demographic, socioeconomic, geographic, and population trends and changes in uses and values of wilderness?

   c. Visitor Attitudes and Satisfactions

      Q. Which activities and experiences are dependent on designated wilderness, and can those which are not dependent be better provided elsewhere?

      Q. To what extent does wildlife observation supplement wilderness visitation experiences and satisfactions?

      Q. How does visual evidence of human use affect visitor satisfactions?

   d. Trends and Projections of Indices of the Recreational Values of Wilderness

      Q. What set of factors determines and can be used for projecting recreational values of wilderness?

2. Extent of Scientific Use

   Q. How does wilderness preservation benefit science and how can science benefits be measured?

3. Educational and Personal Development Uses

   Q. What are the nature of and trends in growth of human resource programs and uses of wilderness, for example, Rights of Passage, Vision Quest, Leadership Schools, Boy Scouts?

   Q. How essential are wilderness settings to the success of human resource programs?

4. Ecosystem Representation and Environmental Preservation Values

   Q. How can preservation uses and values be expressed so that they can be compared with other uses?

   a. Noncomforming uses (minerals, water, grazing, subsistence uses, etc.)

Q. What are the extent and effect of extractive uses on long-term ecosystem dynamics?

5. Total Demand and Relative Rates of Change in the Components of Total Demand

   Q. Can a composite demand measure, including the recreational, scientific, and other wilderness demands, be structured and estimated?

C. The Resource

Q. Is there a model that identifies the factors, resources, and relationships critical to assessing wilderness resources? For example, do Limits of Acceptable Change, the Recreation Opportunity Spectrum, or the Ecoregion System provide adequate models?

(Note: Whatever system is selected, it must be broadly reflective of the many values and management concerns of wilderness.)

1. The National Wilderness Preservation System by Agency and Region

   a. Acreage and condition of designated and study areas

      Q. How can the quantity and condition of the wilderness resource be best expressed to represent different concepts of wilderness values?

      Q. What methodology, models, and techniques exist for assessing the visual, experiential, and ecological quality of wilderness?

   b. Recreation trails, access heads, motorized access, camps, and shelters

      Q. What sources of data are available for quantifying recreational facilities and developments in wilderness areas?

   c. Ecosystem representation

      (1) Acres by ecosystem and adequacy of representation

         Q. What are the critical ecosystems that could be represented by wilderness, and to what extent are these ecosystems currently represented?

         Q. How can the adequacy of ecosystem representation best be measured?

      (2) Critical threatened and endangered plant and animal habitat

         Q. To what extent do wilderness areas serve as enclaves for protecting certain plant and wildlife species, for example, mountain caribou, condors?

   d. Private inholdings

   e. Changes in legislative definition

      Q. Are the definitions of suitability and standards of management of new wilderness areas different from the original legislation, and can these differences be systematically described?

2. Nonsystem Areas With Recreation Experience Substitute Potential

   Q. How can roadless areas that can provide substitute recreational experiences be identified and evaluated for their potential substitution for designated wilderness?

3. State and Private Wilderness Systems and Areas

   Q. In which States do State wilderness systems exist, and how much and what types of areas exist?

   Q. To what degree do State and private wilderness areas provide wilderness benefits, and to what extent do these complement the benefits provided by the National System?

4. Comparison of Management Philosophies and Policies Among Federal Agencies, States, and Private Concerns

5. Prospective Changes in Wilderness Designations

   a. Study and other roadless areas by agency, region, and ecosystem

      Q. What assumptions and rationales are necessary as bases for projecting prospective trends in wilderness allocations?

D. Evaluation of the Relative Changes in Wilderness Demand and Supply

Q. How can values and future levels of wilderness recreation demand best be estimated?

Q. What criteria or standards are appropriate for defining optimum wilderness allocation and management for recreational and nonrecreational uses?

Q. How can nonrecreational demand and supply comparisons be formulated and carried out?

1. Recreation Visitor Days (RVD's) of Use Versus RVD's of Capacity Over Time

2. Projections of Wilderness Recreation Supply and Demand

3. Values per RVD of Wilderness Recreation by Region

4. Option, Existence, and Bequest Values of Wilderness

   Q. Does membership and support of wilderness advocacy organizations provide a measure of these demands and values?

5. Trend Projection of Nonrecreational Wilderness Demand

E. Implications of Demand-Supply Comparisons

1. Social

   Q. Do wilderness recreation experiences contribute to expressions of personal and social well being, such as increased productivity?

   Q. To what extent does wilderness serve as a rallying point for conservation concerns and how then does wilderness concern affect the status and conservation of other natural resources?

   a. Distribution of opportunities for wilderness recreation relative to distribution of population

Q. How can opportunities for similar experiences in nondesignated areas be considered in weighing the relative availabilities of wilderness recreation opportunities?

b. Possible discriminatory effects of supply-demand situation, including regulatory changes

Q. Are some wilderness uses and users being displaced, and for what reasons?

Q. To what extent are nonrecreational uses affected by regulations and practices that apply to recreation?

c. Social and cultural values of subsistence uses

Q. What data exist to describe subsistence uses and the interaction of these uses with other uses and values of wilderness?

2. Economic

Q. What are the existing estimates and methodologies for estimating direct and secondary economic consequences of wilderness?

(Comment: The current Public Area Recreation Visitors Survey incorporated a separate sample of NFS wilderness areas which will yield recreational use demand functions and profiles of visitor expenditures in local economies.)

a. Indirect benefits and opportunity costs of increased wilderness allocation

Q. What is the nature and magnitude of wildlife, water, range, timber, and other benefits and opportunity costs associated with increased wilderness allocation?

Q. How can indirect benefits and opportunity costs be estimated?

b. Economic impacts of projected changes in wilderness recreational use and supply

Q. To what extent and how are local economies affected by wilderness allocations and policies?

c. Potential impacts of wilderness recreation user fees

d. Contribution of subsistence uses to economic well being of rural communities

e. Management cost implications of evolving legislative definition of wilderness, including air and water quality standards and inclusion of smaller areas

3. Environmental

a. Air and water quality implications in surrounding areas resulting from adherence to wilderness standards

b. Forest insect and disease spread potential from protected wilderness areas

c. Interactions between uses of designated wilderness and surrounding lands

Q. How do designated wilderness areas and the land and land uses surrounding these areas interact in terms of economic, developmental, and environmental changes?

F. Opportunities to Improve Wilderness Management

(Comment: These opportunities will be identified in the analysis in sections A-E. The peer panel of experts, which convened at Nacogdoches and at Fort Collins, provided ideas, proposed strategies, identified data and information sources, and provided review on such questions as the relationships or tradeoffs between increased management of existing wilderness and new allocations in producing needed wilderness outputs.)

Q. What are the environmental protection and management costs associated with full implementation of wilderness standards as defined by legislation?

Q. What is the relationship or tradeoff between changes in wilderness allocations, wilderness management, and the values produced?

Q. Is it possible that primitive recreation experiences can be provided more efficiently in nondesignated, semiprimitive areas where greater flexibility in management is possible?

Q. What is the relationship between the quality of wilderness experiences and intensity of management and regulation?

Q. What are the more promising opportunities to improve the management of wilderness, and what are the principal obstacles to implementing these improvements?

Q. How should wilderness user fees be applied? What are the costs of alternative fee collection strategies? Can "peak pricing" be implemented? What portion of social costs should be recovered through fees?

Q. How can increased benefits from reduced congestion on existing sites or trails be accounted for in management and allocation decisions?

In the final phases of the RPA Assessment of wilderness, we will identify and describe obstacles to achievement of wilderness objectives. Such obstacles as rising costs, impinging external environmental threats, and competing resource demands will be considered. From the analysis of these potential obstacles will come implications for development of management, research, and assistance programs. These implications will be reported to the Forest Service, the U.S. Department of Agriculture Secretary's Office, the Office of Management and Budget, and the Congress for consideration of agency budgets, programs, and policies.

CRITICAL ISSUES AND THE NEED FOR ASSESSMENT RESEARCH

The issues and questions about wilderness can be grouped into two categories: (1) those pertaining to allocation, and (2) those pertaining to policy and management. Allocational questions address how much, what kind, and where more (or less) designated wilderness is needed. Policy and management questions pertain mostly to the guidelines, rules, and practices applied to already designated wilderness. One of the more important questions fits neither category: What is the relationship between more or less allocation and more or less management in meeting wilderness demands?

Most of the questions identified in the preceding outline have to do with policy and management. Among these, we will concentrate mainly on policy questions because policy making is the major reason for conducting a national assessment. Issues and research pertaining mostly to management have been addressed in the publications resulting from the National Wilderness Management Workshop (Moscow, ID, October 1983).

Among policy-related questions are those that are researchable and those that are not because their answers must be derived through political or other social choices. Below we have identified the policy-oriented questions that we perceive to be researchable and, therefore, which define a wilderness assessment research agenda. Identification of researchable questions is based on two criteria:

1. The question can be addressed and information provided without having to make a value judgment in terms of "what should be."
2. The question asks how to measure, identify, or predict some attribute of wilderness demand or supply (methodology); it seeks to portray meanings, orderings, changes, or differences that are relevant (description); or it addresses a need for a meaningful framework for abstracting, understanding, and predicting wilderness resource or user behavior changes (theory development).

The priority we have placed upon the researchable questions reflects: (1) the immediacy of the need to know because the issue addressed is currently pressing, and (2) the importance of developing the method, description, or theory as an essential ingredient for improving wilderness assessment capability.

Following in highly abstract form are our perceptions of the six highest priority missions for wilderness assessment research. An essential first step in undertaking such a research effort must be to provide a model, system, or definitional framework within which to comprehensively consider and analyze the values, benefits, management concerns, and resource attributes of wilderness.

Benefits.—Conceptualize, test, and specify the units of measure and the methods of measuring and projecting the experiential attributes, values, and benefits of wilderness in terms suitable for policy evaluation and decisionmaking.

Vicarious Values.—Provide definitions and methods for estimating and develop estimates of the existence, option, and bequest values of wilderness.

Resources.—Develop a wilderness resource evaluation model that (1) represents the multiple resource dimensions relevant to the various human values attached to wilderness (recreational and nonrecreational), and (2) represents the biological and physical properties and interactions of wilderness.

Recreational Capacity.—Develop efficient measures of the recreational capacity and of the interactions of recreational use with the natural system dynamics of wilderness.

Interactions.—Evaluate the interaction of wilderness with outside-of-wilderness air, water, soil, faunal, floral, and social conditions and changes.

Management-Policy Relationships.—Estimate and provide guidelines for evaluating tradeoffs between management and allocation for meeting changing demands for wilderness.

It is clear that the contents of the above six research missions are highly interdependent. They all deal with the same designated or other roadless areas. Obviously, then, research applied to these missions must be highly coordinated within a common framework and definitional structure. The RPA Assessment seems to provide the early stages of a feasible framework. RPA also provides a targeted end use for this policy-oriented wilderness research. Symbiotically, the RPA Wilderness Assessment can benefit not only from the data and analyses that would result from this research agenda, but also from the evolution of understanding and resultant improvements in an assessment framework that would flow from increased understanding. Thus, it is further obvious that benefits may be realized with a solid connection between the Wilderness Assessment process and a coordinated policy research program.

NEED FOR CONTINUOUS ASSESSMENT AND RESEARCH

The wilderness assessment has three main components: (1) examination of the status of and changes in demands and supplies of wilderness resources; (2) projection of future changes and the social, economic, and environmental consequences of those changes; and (3) interpretation of the implications of the current and probable future situations for legislation, policy, and management. Research provides the methods and data for measuring change and the theory for interpreting its implications. The process of change is continuous, so continuing research is needed to incorporate new knowledge into our accumulated body of knowledge and methods. New knowledge, beyond that for periodic assessments, is needed to meet the needs of decisionmakers as they face continuously unfolding developments. One outstanding example is the need for data and methods to support the implementation and monitoring phases of the land management planning mandated for National Forests. Previous land planning work has been hampered by voids in data and methods.

The need for ongoing wilderness policy research, then, is driven not only by the need for a periodic snapshot of the demand and supply situation (an assessment report) but also by the continuing flow of questions and issues wrought by a society in flux. Over our short history of intensive, one-at-a-time peeks at where we are (for example, the Outdoor Recreation Resources Review Commission of 1960, the Public Land Law Review Commission of 1970, the Outdoor Recreation Policy Review Group of 1982, and the President's Commission on Americans Outdoors of 1985), it has become painfully obvious that we need a continuous assessment and research process. Each time we stop to take this peek, we discover and bemoan the lack of data, methods, and forecasts. Each time we vow to do something about it, so that next time we will be prepared to satisfy needs and answer questions.

The President's Commission on Americans Outdoors is likely to choose not to examine in detail the demand and supply situation in the United States simply because it does not have the time or resources to generate the information. The necessary information certainly does not already exist. Thus far, each time a new need has surfaced, we have suffered from the void of an ongoing assessment and research program that would maintain and update continuously the data, methods, and analyses needed to make fully informed judgments.

The current organization of the Forest Service's RPA Assessment could be the beginning of a more comprehensive ongoing partnership between wilderness research and policy evaluation. Leading wilderness researchers have been asked to review a proposed outline of analysis plans and needs. They have shared questions believed to represent significant barriers to carrying out the intended analyses. Because the upcoming RPA Wilderness Assessment is housed within a research project at Athens, GA, a vehicle exists for pursuing research before, during, and after the assessment. Involvement of key researchers provides a tap to the most current knowledge and technology. It provides an interface with the expertise needed to address voids in knowledge and technology. It is our hope that something like the current marriage between the RPA Assessment and research can be continued so that we can avoid the costly stop-start mode so typical of regional and national planning and assessment.

AUTHORS

H. Kenneth Cordell
Project Leader and National Assessment Specialist
U.S. Department of Agriculture, Forest Service
Southeastern Forest Experiment Station
Outdoor Recreation and Wilderness Assessment Research
Athens, GA 30602

Alan E. Watson
Assistant Professor
Georgia Southern College
Department of Recreation and Leisure Studies
Statesboro, GA 30458

Section 2. State-of-Knowledge for Wilderness Resource Research

THE ROLE OF FIRE IN WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

Bruce M. Kilgore

ABSTRACT

Literature from the United States, Canada, and Australia is reviewed to summarize knowledge concerning fire history, effects of fire, fire behavior, what is "natural," the role of Indian burning, the role of prescribed fires, effects on wildlife, insects and disease, and nutrient cycling, and the role of stand replacement fires in wilderness ecosystems. Opportunities and priorities for further study on the role of fire in wilderness are suggested. Unresolved questions and problems are presented.

INTRODUCTION

Research on the role of fire in natural ecosystems and, specifically, the impacts of fire on wilderness values, has been an important part of fire research in the past few decades. Pyne (1985) feels that wilderness fire "reoriented fire research into biological topics and fire effects at large, both ecological and economic." It also compelled a fundamental separation of wildland fires into two broad categories, wild and prescribed.

This paper will attempt to summarize what we know about (1) the fire history of various wilderness ecosystems; (2) fire effects in these wilderness ecosystems; (3) fire behavior in wilderness ecosystems; and (4) "wilderness fire," involving such special philosophical concerns as (a) what is "natural;" (b) the role of Indian burning; (c) the role of planned or scheduled prescribed fires; and (d) the role of high-intensity, stand-replacing fires in these natural ecosystems.

Conceptually, the role of fire in all ecosystems managed for natural values—such as research natural areas (Kilgore 1984)—is of concern. In practice, the dominant management interest and primary research information to date come from the large wilderness units in National Forests and National Parks where impacts from adjacent managed vegetation are less. Hence, I will tend to focus discussion primarily on these areas, while attempting to discuss principles and insights that will be meaningful in any ecosystem managed for natural values.

I will rely primarily on data from literature published in the United States, Australia, and Canada, because, as Parsons (1981) noted, with the exception of "Australia and parts of Africa, where prescribed burning . . . has been utilized . . . to perpetuate native communities for many years (Hodgson 1967; Phillips 1974), there is little evidence of other countries showing interest [in using fire to maintain natural ecosystems]." Emphasis will be on the effects of fire on resources, with only minor reference to relationships involving human use of wilderness, such as air quality and the impacts of fire on visitor experiences. While solid data from any source have been sought, there tends to be a geographical emphasis on the Western United States, largely because much of the primary wilderness resource and research results tend to focus there.

The Role of Philosophy and Policy

Elements of philosophy and policy have considerably influenced research on wilderness fire. Factual data on the role of fire in various ecosystems, involving both fire history and fire effects, provided the ecological and theoretical basis for fire management (Kilgore 1976) and for research on wilderness fire. The need for additional research on the "natural" role of fire and philosophical support for accepting what is "natural" in wilderness ecosystems were emphasized to managers and the public by the popular (sometimes almost poetic) and widely recognized ecological statements of three men—one a manager, the other two scientists—who had broad vision and philosophical-ecological bent. These men were: (1) Robert Marshall, one of the original founders of The Wilderness Society (see Winter 1984 issue of **Wilderness**, quarterly publication of The Wilderness Society); (2) Aldo Leopold, the father of game management, who was closely associated with Marshall in establishing the first National Forest Wilderness—the Gila in New Mexico (Leopold 1921, 1949); and (3) A. Starker Leopold, one of Aldo's sons, who was chairman of the committee that prepared the widely quoted Leopold Report of 1963 (Leopold and others 1963). That report made major recommendations for revision of National Park Service resource management policy, including fire management. Impetus for work done by National Park Service scientists (and by other agencies as well) was provided by the Leopold Report. For the Park Service, this was supplemented by direct consultation with Starker Leopold, who served briefly as its chief scientist. His personal involvement was extremely important—both scientifically and politically—in implementing the first natural fire zones in Sequoia-Kings Canyon National Parks in 1968 and in gaining support for initiating early research on the impacts of fire in these wilderness zones.

GENERAL EVOLUTION OF RESEARCH ON FIRE IN WILDERNESS

In reacting to the concept of wilderness fire research, C. E. Van Wagner once asked, "Is this a new division of fire research in general? Where do the more traditional features of fire behavior and the biological results of fire effects fit?" (Van Wagner, personal communication 1985). My answer is that if wilderness fire research is restricted to direct, management-oriented studies, then it becomes very narrow and somewhat isolated from the data most needed to make it useful. If not so restricted, it becomes very broad and includes much of fire effects research in general. For the purposes of this discussion, therefore, wilderness fire research includes (1) studies of fire history, behavior, and effects that apply to ecosystems most strongly involved with wilderness, parks, and other natural areas; and (2) special studies to determine what is "natural," involving both philosophical and policy matters as these relate to Indian burning, agency-ignited fires, the role of high-intensity, stand-replacing fires, and the impact of fire suppression on fuel accumulation and forest structure.

Shifting Focus of Fire Research

Initial emphasis in fire effects research was on how to improve fire suppression techniques and on case studies of damage caused by fire in given ecosystems (Show and Kotok 1924, 1930). Most of these studies were not carried out in natural systems. Federal and State land management agencies were so committed to total exclusion of fire that there was "reluctance to promote research or release results which seemed to jeopardize success" of other agency fire projects such as fire suppression (Schiff 1962).

This early emphasis on the negative aspects of fire—or fire damage—was gradually changed by the work of such early plant ecologists as Clements, Cowles, Hall, Ramaley, and Cooper (Bock 1976) working largely with lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*). In addition, a group of fire scientists in the South known as the "Dixie Pioneers" (Komarek 1973) challenged the concept that all fires are bad. This group of four men included a forester (Chapman 1912), a botanist (Harper 1913), an animal husbandman (Greene 1931), a wildlife scientist (Stoddard 1935), and several Forest Service scientists from southern experiment stations (Heyward and Barnette 1934). In combination, the work of these southern fire scientists showed that prescribed burning could be beneficial to longleaf pine, cattle, and quail without damaging the chemical composition of forest soils in the region.

Western counterparts to these southern scientists included two foresters with the Bureau of Indian Affairs (BIA) and a forestry professor in California. The combined ponderosa pine research and experimental management efforts of Harold Weaver (1943) in Washington, Oregon, and Arizona, Harry Kallander in Arizona, and Harold Biswell of the University of California at Berkeley led to three conclusions: (1) that ponderosa pine forests had developed in nature with frequent low-intensity fires; (2) that fire exclusion has resulted in extreme fire hazards today; and (3) that prescribed burning by means of low-intensity fires can reduce fuels while simulating other ecological impacts of natural burning (Biswell 1967). Early research on the role of fire in Everglades National Park in Florida (Robertson 1953) and the Boundary Waters Canoe Area in Minnesota (Heinselman 1973) illustrated the importance of natural fire questions beyond western wilderness. More recently, natural fire management programs implemented in National Parks and National Forest Wildernesses in the West have led to research results that further our understanding of the role of fire in natural ecosystems (Kilgore and Briggs 1972; Kilgore 1973a; Mutch 1974; Despain and Sellers 1977; van Wagtendonk 1978; Parsons and DeBenedetti 1979).

Research questions initially began as some form of "How can we best suppress fires on all lands, including parks and wilderness?" This gradually changed to such specific questions as "Does fire always cause soil erosion and always harm wildlife?" Somewhere in the late 1950's and early 1960's, we may have switched from a "fire is bad" to a "fire is good" approach before moving to the more objective question, "How does fire affect various resources (wildlife, soil, water, and vegetation)?" Fire is not always good for wildlife or plants. Some papers seem to imply that high plant/animal diversity in early succession means disturbance is good and old stands with lower diversity are decadent. As applied to wilderness, fire effects that best mimic the natural ecosystem are good—they may be from either low or high intensity, frequent or very infrequent fires.

With the advent of the Leopold Report (Leopold and others 1963), the focus shifted rapidly to the question of whether fire could be allowed to burn in wilderness and park lands without damaging the resource. The current research question has become "How can we best restore fire to its natural role in wilderness?" Subquestions involved include: (1) What is "natural?" (Kilgore 1985b); (2) what changes were caused by fire suppression? (van Wagtendonk 1985; Habeck 1985; Brown 1985); (3) do we need to use human-ignited prescribed fires to restore or maintain a semblance of naturalness? (Kilgore 1982; Worf 1985; Lucas 1985; Kilgore 1985a); and (4) how precise do we need to be in restoring vegetation in parks and wilderness? (Bonnicksen 1985; Bancroft and others 1985; Parsons and others 1986; Bonnicksen and Stone in press).

Development of Theoretical Structure of Wilderness Fire Research

A background in basic ecological concepts is necessary to understand how wilderness ecosystems operate (Franklin 1978). We need knowledge of the composition, processes, and structure of forested and other wilderness ecosystems before we can study wilderness fire.

Fire Dependence.—One of the most fundamental concepts, on which all wilderness fire research is based, is that the natural state of most ecosystems in wilderness, parks, and other natural areas is fire dependent. The early work of Clements (1910) in lodgepole pine, Maissurow (1935) in white pine (*Pinus monticola*), Weaver (1943) in ponderosa pine, Robertson (1953) in subclimax slash pine (*Pinus elliotti*) of Everglades National Park, Spurr (1954) in forests of Itasca State Park in Minnesota, and Cooper (1961) in ponderosa pine forests in Arizona helped strengthen this understanding. Ahlgren and Ahlgren (1960) synthesized much of the general ecological effects literature available prior to 1960. Hartesveldt and his colleagues at San Jose State College in California conducted important studies on the role of fire in giant sequoia (*Sequoiadendron giganteum*) groves in Sequoia-Kings Canyon and Yosemite National Parks, California (Hartesveldt 1964; Hartesveldt and Harvey 1967; Harvey and others 1980). At the same time, studies in the sequoia-mixed conifer forest were being carried out by Biswell and Kilgore (Biswell and others 1966, 1968; Kilgore and Biswell 1971; Kilgore 1973a,b). All of these studies confirmed the dependence of these ecosystems on a regular recurrence of fire.

Mutch's 1970 paper in **Ecology** was an important conceptual contribution. He hypothesized that, "Plant communities may be ignited accidentally or randomly, but the character of burning is not random. . . . Fire-dependent plant communities burn more readily than nonfire-dependent communities because natural selection has favored development of characteristics that make them more flammable." The significance of this hypothesis is tremendous. At the risk of being anthropomorphic, ponderosa pine and similar fire-dependent ecosystems, in effect, "make sure they burn" by dropping highly flammable dry pine needles at the base of the parent tree annually; then when fire occurs, pines gain a competitive advantage over other species that occur in mixed conifer communities.

Fire performs a number of roles in most ecosystems or plant communities. These can be summarized in various ways, but the following eight statements paraphrase the roles previously suggested by Kilgore (1972, 1973b), Wright and Heinselman (1973), and Heinselman (1978):

1. Fire controls plant community composition.
2. Fire terminates and renews succession.
3. Fire controls the scale of vegetation mosaic.
4. Fire regulates fuel accumulations.
5. Fire controls nutrient cycles and energy flows.
6. Fire impacts wildlife habitat.
7. Fire interacts with insects and diseases.
8. Fire impacts productivity, diversity, and stability of the ecosystem.

From 1962 to 1976, the annual **Proceedings of the Tall Timbers Fire Ecology Conference** provided an important forum for exchange of ecological knowledge about such effects of fire in fire-dependent ecosystems. Since 1970, an ever-increasing number of research reports on the fire ecology of various vegetation types have been published. Many have been summarized in books, review articles, or annotated bibliographies (Wright and Heinselman 1973; Kozlowski and Ahlgren 1974; Baker 1975; Heinselman 1978; Mooney and others 1981; Wright and Bailey 1982). A growing number of symposia have been held in various parts of the United States, Australia, and Canada, where scientists and managers have discussed the role of fire in various geographic areas and vegetation types; proceedings have been published summarizing these ideas. Most recent among these are the symposia on mediterranean-climate ecosystems (Mooney and Conrad 1977; Conrad and Oechel 1982); Australia (Gill and others 1981); and wilderness, parks, and other natural areas (Lotan and others 1985).

Fire History.—A second fundamental idea in the theoretical structure of wilderness fire research is fire history. By fire history, we mean the frequency (interval between fires), intensity or severity, and the sizes and seasons of past fires in a given ecosystem. Study of fire history has come to be almost synonymous with study of fire scars found in the radial growth patterns of both softwood and hardwood tree species. Use of aerial photographs for mapping stands arising after severe fires and increment core dating of fire-origin age classes on the ground are other means of obtaining fire history information, particularly in forests in which stand-replacing fires are common. As an example, in his monumental work in the Boundary Waters Canoe Area, Heinselman (1973) determined detailed stand origin and fire year maps and individual fire year dates for a 1-million-acre study area. His work included careful interpretation of fire history since 1595, the role of climatic and physiographic factors, detailed discussions of paleoecological evidence of fire, ignition sources and fuel interactions, and succession, diversity, and stability as they relate to fire. Heinselman also established the concept of "natural fire rotation." This concept is similar to Van Wagner's "fire cycle" (personal communication 1978) and Tande's (1979) "fire return interval." The most complete current bibliography of fire history research (Mastroguiseppe and others 1983) contains 520 references.

Fire Regimes.—The third major concept of wilderness fire research is fire regimes, defined by Heinselman (1985) as "the kind of fire activity that characterizes a specific region." We classify ecosystems into varying fire regimes made up of factors such as (1) fire type and intensity (distinguishing crown fires or severe surface fires from low-intensity surface fires); (2) frequency or return intervals typical for the vegetation type or geographic unit; (3) size of area burned in a typical ecologically significant fire; (4) typical season of burning; (5) pattern of burn; and (6) severity or depth of burn (Gill 1973; Heinselman 1978, 1981; Methven 1978; Sando 1978; Keeley 1981). The first two factors are most important in the fire regimes suggested by Heinselman (1978, 1981), Sando (1978), and Kilgore (1981).

Pyne (1984) sees fire regime as an "amorphous [and] intuitive rather than rigorous . . . concept which seeks to reconcile the physical nature of fire with the biological context within which it burns." While it attempts a great deal in synthesizing broad ecological and physical principles into a few categories, the fire regime concept does lend a semblance of order to an otherwise very confusing, contradictory, and voluminous literature of fire ecology that tends to be highly specific and descriptive only of a particular fire at a particular time and site (Pyne 1984).

Development of Wilderness Fire Research Methods

Broadly speaking, fire research can either (1) follow a process of developing theoretical models of wildland fire interactions with vegetation and fuels in various ecosystems and then checking how well such models can predict real-world situations; or (2) use a more empirical approach, emphasizing observations and measurements of real-life interactions among fire, vegetation, and fuels, with all their complexity. While there are hundreds of physical, biological, and socioeconomic models related to wildland fire management to date (Simard 1981b), much is lacking in the way of theory, data, and experience in the short history of modeling in fire management. A number of models and their related support systems (Rothermel 1980) have been developed in the fire behavior field that appear to be extremely useful in representing fuels for estimating fire behavior, but relatively few models try to integrate changes in vegetation and fuels over time with fire frequency and intensity. All have integrated the theoretical and empirical approaches due to lack of data.

Examples of these more complex models are FYRCYL (van Wagtendonk 1972), a computer model of the natural fire cycle that simulates fuel accumulations, lightning fires, and subsequent fuel reductions in frequent, low-intensity surface fire regimes in the Sierra Nevada; FORFLOR (Agee 1973), which was developed to investigate erosion hazards caused by lightning ignitions; a structural model developed by Bonnicksen and Stone (1982b) that predicts age, number of vertical layers, and species composition of tree aggregations in a giant sequoia-mixed conifer forest; and a gap model of succession in mixed conifer forest using fire (Kercher and Axelrod 1984) as cited in Agee and Huff (this proceedings). Several of these models have shortcomings (van Wagtendonk 1985). The original FYRCYL did not have a vegetation subroutine, so effects of succession and fuel accumulation were not considered, while Bonnicksen and Stone's (1982b) model did not produce fire frequencies and intensities. A revised recent FYRCYL model (van Wagtendonk 1985) combines vegetation, fuel, weather, and lightning to simulate fires that interact with vegetation and fuels and predicts effects of no fire, lightning fire, and suppression scenarios on fuel energy, basal area, and density by species.

Another approach is the empirical/field method emphasizing observations and measurements of real forest fires. Fire research in Canada has tended to follow this method (Van Wagner 1984). Theory was not ignored; physics and math complemented essential field observations but never supplanted them. The drawbacks of this strategy are that independent variables are less controllable and the results of a particular study are less widely applicable. Yet the combustion process and its impacts were felt to be so complex that modeling forest fires in the laboratory would be less productive than letting the forest be the empirical integrator of all fire effects, short-term and long-term.

Fire History Methodology.— Looking specifically at research methods used in fire history, two of the important early publications describing use of tree-ring technology for determining fire history were those by Clements (1910) working with lodgepole pine in Colorado and Weaver (1951) working with ponderosa pine in many areas of the West. The recent increased need for information about past fire history in general (and fire frequency specifically) to support wilderness fire management programs has given a tremendous push to development of more sophisticated and practical techniques in fire history research.

Some of the approaches now in use to determine fire frequency, fire intensity, and fire size in various wilderness ecosystems (Alexander 1980) include:

1. Use of both modern fire records and presettlement written records such as early diaries and maps by Jesuit priests or explorers and reports of early government agency personnel.
2. Use of oral records of Indian fires (Lewis 1977, 1980, 1985; Barrett 1980, 1981).
3. Use of aerial photographs and satellite imagery to map fire patterns or mosaics (Heinselman 1973; Tande 1979; Alexander 1980; Hawkes 1980).
4. Retaking early photographs from the same photo site to illustrate vegetative changes in the absence of fire (Progulske 1974; Gruell 1980, 1983; Houston 1982).
5. Development of stand origin and fire history maps from forest inventory maps plus stand age data.
6. Use of dendroclimatological techniques to determine relationships of past climate to fire history (Alexander 1978, 1980).
7. Use of paleoclimatic reconstruction techniques involving charcoal stratigraphy and charcoal-pollen analyses (Terasmae 1967; Swain 1973; Weeks 1976; Cwynar 1977; Mehringer and others 1977; Hemphill 1983; Smith 1983).
8. Computer modeling of stand-age class distribution projections over time (Suffling and others 1980). Both van Wagtendonk (1972) and Agee and Flewelling (1983) used climatic data with spread data to simulate fire frequency, rather than relying on age class or fire scar data.
9. Use of tree-ring increment cores from fire-initiated stands and fire scar data from cross-sections or wedges from either dead or living trees to determine intervals between fires and some indications of areal extent of fires and fire intensities.

The most common method of determining fire history in forests is by dating fire scars using techniques similar to those developed in dendrochronology; this is supplemented by increment core records from stands that originated after high-intensity fires. The standard form of this technique (Arno and Sneck 1977) has five main steps (McBride 1983). These steps and their strengths and weaknesses are:

1. Selection of samples: It is essential that they be stratified into units expected to have similar fire occurrence and behavior (Kilgore and Taylor 1979; McBride 1983) for grouped data to be meaningful.
2. Removal of samples from trees: Techniques range from complete cross-sections, wedges, and thin wafers (Heinselman 1973; McBride and Laven 1976; Arno and Sneck 1977; Dieterich 1980b) to increment cores (least accurate, but also least impact on wilderness resources) (Heinselman 1978 in Alexander 1980; Means 1985).
3. Dating fire scars: Major problems here involve (a) recognizing fire scars and separating them from wounds caused by frost crack, root rot, insects, or other sources (Row and others 1974; McBride 1983; Stuart and others 1983), and (b) missing, discontinuous, or false rings. The latter problems can be solved by crossdating (Madany and others 1982), matching a ring pattern of wide and narrow rings from one specimen to another, or

through use of recent, more sophisticated techniques involving x-ray density measurements and computer processing of data (Parker 1972). Achieving greater accuracy through crossdating, however, is time consuming and expensive, and not always necessary.

4. Summarizing fire data: Individual fire dates are then combined to produce master fire chronologies for a sizable area or composite fire intervals for a smaller area (Arno and Sneck 1977; Kilgore and Taylor 1979; Dieterich 1980; Arno and Peterson 1983).

5. Calculation of mean fire-free intervals: Such intervals can be calculated for different size areas, different aspects or elevations, different habitat types, different historical time periods, and different sizes and intensities of fires (Kilgore and Taylor 1979; McBride 1983). The size of area being considered is extremely important in determining intervals between fires. This can be calculated for the individual tree, a small group of trees, a large stand (200-800 acres), or an entire watershed or forest region (Kilgore and Taylor 1979; McBride 1983; Arno and Peterson 1983; Dieterich and Swetnam 1984). In general, the larger the unit size, the greater the number of fires and the shorter the interval between them without any basic change in ecosystem function (Kilgore 1981). Arno and Peterson (1983) suggested that smaller sized units may be best in areas where trees are long-lived and readily fire scarred, while larger units may be required to piece together fire history in areas where the oldest surviving trees are scattered or very resistant to scarring.

Fire Effects Methodology.—A number of study designs and techniques have been used to measure the broad spectrum of variables involved in the effects of various intensities of fire on different vegetative types and ecosystems. A fairly standard experimental design for obtaining such fire effects data from prescribed burning (see Kilgore 1971a,b, 1973a; Agee 1973; van Wagtendonk 1974) is outlined by these six steps:

1. Develop testable hypotheses from a specific problem statement.
2. Decide on applicable methods after setting up an appropriate experimental design.
3. Establish several experimental burn plots or transects and control plots or transects; measure appropriate vegetative, fuels, soil, water, air, or wildlife variables prior to the burn.
4. Burn the sites under known weather and fire behavior parameters.
5. Make postburn measurements of the same variables on both burn and control plots.
6. Analyze the changes in variables due to impact of the given intensity of prescribed fire under known weather conditions.

Depending on the objectives, such before, during, and after studies of fire impacts can be directed toward gathering data and analyzing effects by particular species; ecosystems or vegetation types; particular well-known fires; specific variables of interest, such as fuels or wildlife; geographic region; or long-term effects (more than 10 years). Examples of these six approaches are:

1. Fire impacts by species, such as ponderosa pine (Cooper 1960), giant sequoia (Hartesveldt 1964; Harvey and others 1980), redwood (*Sequoia sempervirens*) (Veirs 1982), lodgepole pine (Taylor 1969).
2. Fire effects by ecosystems or vegetation types, such as California red fir (*Abies magnifica*) forests (Kilgore 1971b), sequoia-mixed conifer forest (Kilgore 1973a), ponderosa pine/western larch (*Larix occidentalis*)/Douglas-fir (*Pseudotsuga menziesii*) (Lunan and Habeck 1973).
3. Fire effects by particular wildfire, such as three historical fires in Olympic National Park, WA (Agee and Smith 1984); the Independence Fire of 1979, Selway-Bitterroot Wilderness, ID, the largest natural fire to burn to date under wilderness fire programs (Keown 1980, 1985a); the Little Sioux Fire of 1971, Boundary Waters Canoe Area, MN (Books and others 1971).
4. Fire effects by impacts on specific variables, such as: (a) fuels (Pickford and others 1977; Agee and others 1978); (b) crown scorch (Van Wagner 1973); (c) crown-fire potential (Kilgore and Sando 1975); (d) seedling germination (Kilgore and Biswell 1971); (e) hydrologic properties or water quality (Agee 1973); (f) wildlife, generally, or specific species or groups of species such as birds (Kilgore 1971a; Koehler and Hornocker 1977); and (g) insects or disease (Gara and others 1985).
5. Fire effects by geographic region or wilderness, such as Selway-Bitterroot Wilderness, ID (Habeck 1976); Sequoia National Park, CA (Vankat 1970); Boundary Waters Canoe Area, MN (Heinselman 1973).
6. Long-term fire effects, such as Lyon's (1976, 1984) 21 years of postfire change or chronosequence approaches carefully substituting space for time (Taylor 1969; Huff 1984).

While the study designs noted above have in some cases been developed with wilderness fire research needs in mind, the particular techniques used to measure individual variables are almost always standard methods utilized in all studies of vegetation, soil, water, and wildlife work and, hence, will not be discussed specifically. Descriptions of such standard techniques can be found as follows:

Fuel quantity methods	Brown and others 1982
Fuel moisture methods	Norum and Fischer 1980 Sackett 1980
Weather measurements	Fischer and Hardy 1976
Fire variables	Rothermel and Deeming 1980
Vegetation sampling methods	Brown and others 1982 Britten and Clark 1981 van Wagtendonk and others 1982
Smoke and air quality methods	Mobley and others 1976
Water quality methods	Ponce 1980
Soil exposure methods	Gleason 1957 Beaufait and others 1977
Wildlife populations and habitat measurements	Nudds 1977 Giles 1969 Kendeigh 1944

Fire Behavior Methodology.—Measuring fire behavior is extremely important for meaningful interpretation of ire effects information (Van Wagner and Methven 1978; Methven 1978). Most monitoring efforts on wilderness ires are aimed at obtaining information on fire behavior and weather to assure managers that a given prescribed ire is behaving as predicted or to allow prediction of movement of a wildfire during the next few hours or days, in terms of human safety and impact on property. Variables usually measured are flame length and rate of spread; techniques for making these measurements are covered by Rothermel and Rinehart (1983). From these measurements, fire line intensity and heat per unit area can be calculated (Rothermel and Deeming 1980). Techniques for predicting and estimating rate of spread, flame length, and fire line intensity include nomographs (Albini 1976), the hand-held calculator (Burgan 1979), and computer systems such as BEHAVE (Burgan and Rothermel 1984; Andrews 1986). These techniques are compiled in a manual for field use by Rothermel (1983).

Fire behavior predictions are useful in wilderness fire programs for projecting fire size, perimeter length, and area growth (Keown 1985b), including how large a fire may become. Where size has been used by managers as a prescription criterion, as in Gila Wilderness fire plans (Kilgore 1982), this is a highly important estimate. The present techniques for predicting spotting distance (Albini 1979) and the current effort to predict crown fire potential (Fahnestock 1970; Rothermel 1983; Keown 1985b) offer possible assistance to wilderness fire managers in judging the likelihood of major changes in overall fire activity, including consideration of threat to human life, property, and nonwilderness lands.

Few studies of fire behavior in wilderness have quantified flame length and spread rate and correlated them with fire effects data. In a recent study in Yosemite National Park, CA, behavior predictions and observations were made for more than 230 plots that were burned with prescribed fires in six fuel types, ranging from ponderosa pine through mixed conifer and true fir (*Abies* spp.) to montane chaparral (van Wagtendonk and Botti 1984). Both the National Fire-Danger Rating System (NFDRS) and the Fire Behavior Prediction System (FBPS) tended to overpredict rates of spread and flame lengths for many plots, but underpredictions were common in the mixed conifer and montane chaparral types. "Until custom-built fuel models become available, the NFDRS and FBPS will remain the best predictors of fire behavior" (van Wagtendonk and Botti 1984).

Wilderness Fire Methodology.—Few studies are unique to wilderness or park environments, and hence relatively little has been developed to date that can be thought of as unique methodology for wilderness fire. The types of studies coming closest to this would be those addressing four issues:

1. What is "natural?"

2. How much fuel has accumulated because of fire suppression?

3. What changes in forest structure have resulted from fire suppression (both changes within stands and changes in the mosaic of vegetation communities)?

4. What have been the impacts of allowing natural fires to burn?

These issues are strongly intertwined, and I will not attempt to address them separately. Any special methods or techniques developed to address these issues might be thought of as wilderness fire methods.

Several studies have been carried out recently in Sequoia-Kings Canyon National Parks, CA, to measure unnatural fuel accumulation because of suppression of fire (Parsons 1978; Parsons and DeBenedetti 1979). Traditional fuel measurement techniques were used in these studies, although special interpretation was given to possible changes because of fire suppression. The authors also thoroughly analyzed any suppression-related changes in species composition, age structure, and densities of different size classes of each species.

Sophisticated methods involving several point-pattern analysis techniques have been employed recently by Bonnicksen and Stone (1981, 1982b). These techniques were used to characterize both the present and the presettlement horizontal structure of giant sequoia-mixed conifer forests as mosaics of homogeneous vegetative units called aggregations. These mosaics of aggregations change with respect to each other in both space and time as trees within them grow older and are replaced by younger trees. The proportion of the forest represented by any one age class or species mix, however, will remain about the same (Bonnicksen and Stone 1982b). The absence of fire in this frequent, low-intensity fire regime for the past 50 to 100 years has apparently allowed an abnormal number of aggregations dominated by younger age class true fir to become pole-sized or mature fir.

A method being used to determine effects of allowing natural fires to burn involves establishing plots on several previous fires of known ages. Such chronosequence approaches carefully substitute space for time. Researchers then analyze regrowth of tree and shrub vegetation over time with respect to apparent fire intensity and severity, climatic factors, and vegetative potential (Taylor 1969; Agee and Smith 1984).

RESEARCH RESULTS: RELATIVELY WELL-SUPPORTED KNOWLEDGE

Wilderness fire research is summarized with results from segments of general fire research on fire history, fire behavior, and fire effects. We know a fair amount about the role of fire in various ecosystems, after 70 years of research on particular regions, ecosystems, or species.

While many of these studies were not undertaken in wilderness or parks, the results will be valid for such areas, provided there were no major man-caused modifications of the vegetation or ecosystem being studied. Recent work carried out directly in park and wilderness units can be used to cross-check results from earlier studies in relatively unmodified but nonwilderness vegetative communities.

The concept of fire regimes is a useful framework around which to organize existing fire research knowledge. I will use the following fire regimes for this purpose:

1. Frequent, low-intensity surface fires (1- to 25-year return intervals).

2. Infrequent, low-intensity surface fires (more than 25-year return intervals).

3. Infrequent, high-intensity surface fires (more than 25-year return intervals).

4. Short-return-interval, stand-replacement fires (25- to 100-year return intervals).

5. Variable regime: frequent, low-intensity surface fires and long-return-interval, stand-replacement fires (100- to 300-year return intervals).

6. Very long-return-interval, stand-replacement fires (more than 300-year return intervals).

Certain fire regimes and vegetation types will be covered more thoroughly than others for two reasons: (1) more knowledge is available for some vegetation types; and (2) we need to know more about certain vegetation types and fire regimes. In certain short-return-interval fire regimes, a relatively few years' modification of the natural fire cycle can result in an unnatural ecosystem state. By contrast, a few years' alteration of the fire cycle in 300- to 400-year-return-interval fire regimes would cause relatively minor changes in similar aspects of that ecosystem.

Careful splitting of different physiographic or geographical segments of vegetation types (such as lodgepole pine) under several fire regimes is practical in table 1, but presentation of these finer differences is not practical or helpful in the general text discussion. Hence, I will include species under their most typical fire regime.

Frequent, Low-Intensity Surface Fires

We have more information on fire history, effects, and behavior in this fire regime than any of the others. During presettlement times, frequent, low-intensity surface fires were characteristic of both seral and climax ponderosa pine forests and giant sequoia-mixed conifer forests (Weaver 1951; Cooper 1960; Biswell 1967; Kilgore and Taylor 1979; Kilgore 1981). Certain Douglas-fir and western larch forests in the Rocky Mountains were kept open for centuries by frequent natural burning (Arno 1980) along with insect epidemics and other mortality factors.

The broad principle involved in this fire regime is that fire burns regularly and frequently (every 1 to 25 years) and as such rarely allows the accumulation of organic fuels to a point that higher intensity fires will develop. Few specific studies of fire behavior have been carried out in this regime. Van Wagtendonk (1972, 1974) studied spring surface fires in Yosemite National Park's ponderosa pine and incense-cedar (*Libocedrus decurrens*) forest type. Intensity increased as fuel moisture decreased from 19 to 10 percent, but the maximum intensity measured was 75 Btu per second per foot (61 kcal/s/m). In more recent work in a wider range of fuel types, van Wagtendonk and Botti (1984) found flame lengths of about 1 foot and mean rates of spread between 1 and 2 feet per minute. Such behavior appears to be typical of this fire regime.

Ponderosa Pine Forest.—Fire frequencies in presettlement ponderosa pine forest varied from 2 to 18 years in different parts of its range, with 5 to 12 years being typical (table 1). Fires were probably somewhat more frequent in some climax pine forests than seral stands. Little data are available on fire sizes. In the Gila Wilderness of New Mexico, Swetnam and Dieterich (1985) found 3,000 acres to be a conservative estimate of fire size, although they also found smaller fires recorded on only a few trees.

Mixed Conifer Forest.—In mixed conifer forests where such species as white fir (*Abies concolor*), Douglas-fir, giant sequoia, sugar pine (*Pinus lambertiana*), incense-cedar, and similar species are mixed with ponderosa pine, intervals between fires generally become longer, ranging from 9 to 42 years (table 1). Sizes of fires vary from small fires at frequent intervals to less frequent larger fires (Dieterich 1983). In a sequoia-mixed conifer forest in California, large fires (more than 2,000 acres) burned approximately every 26 years between 1782 and 1858, while moderate-sized fires (40 to 2,000 acres) burned about every 10 years and small fires were even more frequent (Kilgore and Taylor 1979).

Fire's Effects in This Regime.—The impact of fire on plant community composition in the frequent, low-intensity fire regime begins with a role in triggering release of seeds of such serotinous species as giant sequoia (Kilgore and Biswell 1971) and in preparing a seedbed, usually of mineral soil and ash, that is conducive to effective germination and survival of giant sequoia, Douglas-fir, and many species of pine (Hartesveldt and Harvey 1967). Fire also controls species composition by favoring species requiring sunlight such as pines and sequoia over shade-tolerant forms such as white fir and incense-cedar, and fire-resistant and fire-dependent species and associations over nonfire-dependent forms.

Recycling understory vegetation without damaging the overstory canopy greatly is not as dramatic a role as that found in stand-replacement type fire regimes, but it is nonetheless important. In on-site fire history studies in Sequoia-Kings Canyon National Parks, Kilgore and Taylor (1979) found no evidence of intense fires that moved from crown to crown of giant sequoia in the past 400 to 2,000 years. However, small patches of intense surface burning during a prescribed understory burning program resulted in small openings and ideal seedbed conditions for sequoia seedling germination and survival (Kilgore and Biswell 1971). Such conditions probably occurred at various times in the past, due to climatic fluctuations and localized fuel accumulations.

Most forests are made up of a small scale patchwork or mosaic of age classes, successional stages, and vegetation types brought about in part by the different way fires burn in each plant community or fire regime. In ponderosa pine forests of Arizona, for example, Cooper (1961) identified several patterns ranging from (1) a large-scale pattern of differences in density, growth, and species composition induced by local variations in topography and soils, through (2) a patchy mosaic pattern of even-aged groups averaging about 0.2 acre (0.1 ha) in size and maintained largely by fire, to (3) variations in

Table 1.—Summary of fire regimes and fire histories for selected wilderness ecosystems

Fire regime, ecosystem type	Site	Park or wilderness unit involved	Fire frequency (years)	Typical fire size[1]	Source
Frequent, low-intensity surface fires (1-25 year return interval)					
Ponderosa pine forest	Northern Arizona		2-5		Dieterich 1980a
Ponderosa pine forest	Arizona-New Mexico	Gila Wilderness, NM	4-12	Large	Weaver 1951[2]; Swetnam and Dieterich 1985
Ponderosa pine forest	California		8-10	Large (some small)	Show and Kotok 1924; Wagener 1961; McBride and Laven 1976
Ponderosa pine forest	Oregon-Washington		8-18	Large (some small)	Keen 1940; Weaver 1955, 1959; Hall 1976
Ponderosa pine forest	Montana		6-12	Medium	Arno 1980
Ponderosa pine forest	Oregon		14-30	Large	Soeriaatmadja 1966
Mixed conifer forest	Arizona		11	Small	Dieterich 1983
Mixed conifer forest	Arizona		22	Large	Dieterich 1983
Mixed conifer forest	Oregon	Crater Lake NP	9-42		McNeil and Zobel 1980
Sequoia-mixed conifer	California	Sequoia-Kings Canyon NP	9-16	Medium	Kilgore and Taylor 1979
Infrequent, low-intensity surface fires (More than 25 year return interval)					
Lodgepole pine - lower subalpine	Montana		25	Large	Arno 1976
Lodgepole pine - upper subalpine subalpine fir (*Abies lasiocarpa*)	Montana		35	Medium	Arno 1976
Lodgepole pine	Alberta, Canada	Jasper NP	27	Medium	Tande 1979
Lodgepole pine	Montana	Bob Marshall Wilderness	20-40	Medium	Gabriel 1976
Lodgepole pine—red fir	California	Kings Canyon NP	?	Small	Kilgore 1971b
Infrequent, high-intensity surface fires					
Redwood forest - southern unit	Marin County, CA	Muir Woods NM	22-27	Medium to large	Jacobs, Cole, and McBride, in press
Redwood forest - northern unit ● Mesic, near coastal sites	Humboldt County, CA	Redwood NP	250-500	?	Veirs 1982
● Intermediate sites	Humboldt County, CA	Redwood NP	100-200	?	Veirs 1982
● Xeric interior sites	Humboldt County, CA	Redwood NP	50	?	Veirs 1982

Short return interval, stand-replacement fires (25-100 year interval)					
Chaparral	S. California S. California		20-40 30 +	Large Very Large	Byrne 1978 Green in Wright and Bailey 1982
Chaparral, high elevation, north slopes	S. California		50-100	Large	Vogl and Schorr 1972 in Wright and Bailey 1982
Quaking aspen (*Populus tremuloides*)	Colorado Rockies		50-100	Large	Estimated by Hendrickson 1972
Sagebrush-grass	Wyoming	Yellowstone NP	32-70	Large	Houston 1973
Spruce-fir-lodgepole pine higher elevations	Alberta, Canada	Jasper NP	74	Medium	Tande 1979
Lodgepole pine, midelevation	Wyoming	Grand Teton NP	75?	Large	Loope and Gruell 1973
Lodgepole pine	Colorado Rockies		100?	Large?	Clements 1910 in Heinselman 1981
Boreal forest: closed spruce-birch or black spruce	Interior Alaska-NW Yukon		100	Very large	Viereck 1973; Barney 1971 in Heinselman 1981
Lodgeople pine	NE British Columbia		49	Large	Smith 1979 in Heinselman 1981
Jack pine - black spruce	Minnesota	Boundary Waters Canoe Area	50	Very large	Heinselman 1973, revised in Heinselman 1981
Aspen-birch-fir	Minnesota	Boundary Waters Canoe Area	80	Very large	Heinselman 1973, revised in Heinselman 1981
Long return interval, stand-replacement fires (100-300 year intervals)					
Lodgepole pine forest - midelevations	Montana	Bob Marshall Wilderness	150	Large	Gabriel 1976
Douglas-fir forests	Pacific Northwest, Western Washington		200-300 50-400 230	Large Large	Schmidt 1960 Martin and others 1976 Fahnestock and Agee 1983
Boreal forests: spruce	NE British Columbia		103	Large	Smith 1979 in Heinselman 1981
Red-white pines	Minnesota	Boundary Waters Canoe Area	180	Medium	Heinselman 1973, revised in Heinselman 1981
Red-white pines	Minnesota	Itasca State Park	150	Large	Frissell 1973
Very long return interval, stand-replacement fires (More than 300 year interval)					
Lodgepole pine forest	Wyoming	Yellowstone NP	300-400	Large	Romme 1980
Spruce-fir forest	Montana	Bob Marshall Wilderness	300 +	Medium	Gabriel 1976 in Heinselman 1981
Cedar-hemlock forest	Washington	Olympic Peninsula	150 + 500 +	?	Martin and others 1976 Lotan and others 1981
True fir forests	Montana		150 + 800	?	Antos 1977 Fahnestock and Agee 1983
Western hemlock	W. Washington		600	?	Fahnestock and Agee 1983
Cedar-spruce	W. Washington		2000	?	Fahnestock and Agee 1983

---

[1] Fire size classes are: small = 100 acres or less; medium = 101 to 1,000 acres; large = 1,001 to 10,000 acres; very large = more than 10,000 acres (Heinselman 1981).

[2] Early studies by Weaver utilized data from single stumps, without taking advantage of the more complete fire frequency record found on a group of several trees (''cluster'' in Kilgore and Taylor 1979 and composite fire interval in Dieterich 1980b). Thus data tend to be conservative minimums.

stand density within a single even-aged group, primarily due to chance factors in early stand development. Weaver (1967) noted that "Periodic burning causes development of uneven-aged stands, comprised of even-aged groups of trees of various age classes." This has been documented for mixed conifer forests by Bonnicksen and Stone (1981).

Periodic fire plays an important role in regulating dead fuel accumulations. Fire can decrease dead fuels by consuming them or increase them by killing live vegetation. While vegetative biomass accumulates with time, Brown (1985) notes this is not necessarily true for dead fuels because not all biomass is available fuel. Only that portion available to be burned is fuel and this does not include, for example, boles of living trees. Dead branches and boles of trees fall to the ground and become fuel in response to such mortality factors as fire, insects and disease, and wind and snow damage. But as Brown (1985) indicates, these factors occur in an irregular manner not necessarily related to stand age.

In a frequent, low-intensity surface-fire regime, periodic fire plays an important role in maintaining fuels at a minimal level, because natural decay rates are very slow. Biswell and others (1966) found 2 to 3 tons per acre of litter produced yearly directly beneath individual ponderosa pine, sugar pine, and giant sequoia trees. Agee and others (1978) found 1.5 to 2 tons per acre with more random sampling techniques. Such an annual increment of dead fuels may be increased by blowdowns, insects and disease, and wildfire. Under presettlement conditions, after a minimum fuel buildup (usually from 2 to 16 years) fire periodically consumed the accumulation of surface organic materials. The timing of such burns depended on the simultaneous occurrence of an ignition source and suitable weather conditions (van Wagtendonk 1972). Parsons (1978) reported that within 7 years after prescribed burning in a giant sequoia forest, fuels less than 3 inches in diameter had nearly returned to preburn levels and would again support a fire. Larger fuels and duff were still less than half the quantities that had accumulated during more than 60 years of fire exclusion.

Both horizontal and vertical continuities of fuels are also extremely important and are impacted by presence or absence of fires. Regular periodic surface fires in this fire regime have played a role in making gaps in vertical fuel continuity that prevent fires moving from ground to crown. Van Wagner (1977) has summarized some theoretical and empirical conditions necessary for the start and spread of crown fire in regimes characterized by crown fires. Studies by Kilgore and Sando (1975) of vertical live fuel loading in a giant sequoia-mixed conifer forest showed that a relatively low-intensity prescribed fire reduced live crown fuels in the lower canopy by more than half, and the mean height of the crown base was increased from 3 to 16 feet. At the same time, surface fuels 1 year after the fire were reduced sufficiently that forward rate of spread predicted by Rothermel's (1972) fire spread model dropped from 7.5 feet per minute to essentially zero. Thus, removing fuel from the intermediate layer between surface and crown fuels greatly reduced the potential for high intensity surface fires that could lead to crown fires. Chandler and others (1983) noted that "Gaps in vertical continuity of about 1½ flame heights will virtually preclude the fire from burning into the overhead stratum."

Infrequent, Low-Intensity Surface Fires

By definition, fire in this regime burns at more than 25-year intervals but with relatively low intensity. The California red fir and lodgepole pine forests of the subalpine zones of the Sierra Nevada and certain upper subalpine forests of the Rocky Mountains are included in this fire regime. Table 1 shows that fire frequencies in presettlement forests varied from 27 to at least 40 years or more, with detailed information lacking for a number of vegetation communities.

California Mixed Subalpine Forest.—In subalpine forests of whitebark pine (*Pinus albicaulis*), California red fir, and lodgepole pine in the Sierra Nevada, fires often spread slowly or not at all, and they rarely burn the crowns and kill stands of overstory trees (Kilgore and Briggs 1972). Such high-elevation areas have many natural firebreaks such as sparsely vegetated ridges, barren rocky areas, and streams and draws with relatively fire-resistant riparian vegetation. No actual fire histories have been carried out here, but fires of less than one-fourth acre account for more than 75 percent of the fires burning in Sequoia-Kings Canyon (Parsons 1981) and Yosemite National Parks (van Wagtendonk 1978). On the other hand, four fires in these parks from 1968 to 1978 burned more than 2,500 acres and one reached 10,000 acres in size with low-intensity burning over several months. In measurements made on the 4,000-acre Starr King Fire in Yosemite, van Wagtendonk (1978) found rates of spread that varied from 1 inch to 120 feet per hour, with 200 acres being the greatest area covered in 1 day. Intensities varied from 0.29 to 680 Btu/s/foot, and van Wagtendonk characterized the burn as having intensely burned patches separated by lightly burned or unburned areas.

Rocky Mountain Subalpine Forest.—Whereas high-intensity fires have clearly been a major part of the spectrum of fires found in lower subalpine forests of the Rocky Mountains, Arno (1976) concluded that fires are less frequent and intense in the upper subalpine forest because of moist, sparse fuels. In subalpine fir (*Abies lasiocarpa*) forests, fires occurred in a random pattern, with scars on adjacent trees often from different years (Gabriel 1976); this apparently resulted from a high incidence of lightning fires with a low volume of fuel and open stands.

Fire's Effects in This Regime.—The effects of fire on vegetation were related to variations both in species and in burning intensity. While brushfields were almost entirely consumed in one study area, less than 3 percent of the mature California red fir and Jeffrey pine (*Pinus jeffreyi*) were killed (van Wagtendonk 1978). Fire usually had only moderate impact on Jeffrey pine, but California red fir and lodgepole pine either burned intensely or not at all. In earlier studies, fire reduced litter, duff, and humus by about 50 percent. Few older California red fir were affected, but many fir saplings and seedlings were killed resulting in decreased coverage of fir thickets and minor adjustments in successional patterns (Kilgore

1971b). Many mature lodgepole pine were killed, while germination of pine seedlings and seedlings of nine shrubs and herbaceous species was stimulated.

In certain situations in the Rocky Mountains, fire effects similar to those found in the Sierra have been documented. In moist valley bottoms, topographically isolated drainages, and higher elevations, low- to moderate-intensity fires in western larch, Douglas-fir, lodgepole pine, and subalpine fir forests result in thinned stands, reduced fuels, rejuvenated undergrowth, and preparation of seedbeds. This brings about structural changes more than changes in species composition (Davis 1980).

Infrequent, High-Intensity Surface Fires

For most species of vegetation, this non-stand-replacement regime—by definition—holds internal inconsistencies. To be infrequent and high intensity on the one hand, yet remain a surface fire and not a stand-replacing fire on the other, requires special characteristics of the ecosystem or species involved. Although this seems to be a secondary regime for a number of lodgepole pine ecosystem types in subalpine forests of the northern United States (Heinselman 1981), the redwood is a type in which this regime is primary. The redwood has tremendously thick bark and a maximum height of more than 360 feet; as such, mature trees can withstand fairly intense surface burns without killing the trees. In addition, redwood sprouts from the base of the stem as well as along the bole after the stem or foliage is damaged or killed by fire.

Redwood Forest.—Sample fire histories from table 1 indicate a variation from 22 years to between 250 and 500 years in the typical interval between fires. The shorter end of this scale comes from drier inland sites near the southern end of the range of redwood distribution, in Marin County, CA (Jacobs and others in press), while the longer duration represents mesic coastal sites farther north (Veirs 1982). Even with a fire-free interval of 500 years, high-intensity, stand-replacing fires seem to be rare for redwoods. Earlier work by Fritz (1932) showed 45 severe fires over an 1,100-year period in the more northerly area, or about four fires each century on his 30-acre study site.

There are few published observations of fire behavior in redwood forests, but evidence from an 1880 fire would indicate a low-intensity fire (Veirs 1980). In a 1974 fire, spread rates were 2 to 3 feet/minute downhill and only slightly faster uphill, with less than 2-foot flame lengths. In spite of an extremely dry summer, low wind conditions and a slight inversion resulted in a low-intensity fire. Fritz (1932) described much more intense burning following an unprecedented drought in 1929 when fires "burned fiercely" for several weeks and covered more than 10,000 acres.

Fire's Effects in This Regime.—Stone and others (1972) believed that redwoods are seral and strongly dependent on fire and flooding for their perpetuation. Franklin and Dyrness (1973) concurred in this, based on massive fire scars on almost all large redwoods in one area. Others feel the species is climax because of its high shade tolerance (Waring, personal communication, in Franklin and Dyrness 1973). Fairly complex and species-specific responses to fire are involved in the redwood ecosystem. Much of this is still being worked out by various researchers (Veirs 1980, 1982; Jacobs and others in press). Fire effects vary considerably from the drier inland sites to the more mesic coastal sites in this fire regime. In the moist coastal area, for example, Douglas-fir apparently only becomes established following those rare occasions when high-intensity fires make some openings in overstory canopy (Veirs 1982). Other climax species, such as redwood, tanoak (*Lithocarpus densiflorus*), and western hemlock (*Tsuga heterophylla*) do well with or without low-intensity fires.

Short-Return-Interval, Stand-Replacement Fires

This short-return-interval, high-intensity fire regime is characteristic of several shrub vegetation types as well as parts of the lodgepole pine and boreal and near-boreal forests of North America. But the long-return-interval fire regime is more typical for both the boreal forest and lodgepole pine, and such species will, therefore, be described in that section. Chaparral, sagebrush-grass, and quaking aspen (*Populus tremuloides*) have aboveground vegetation that is killed by periodic, intense burning—either crown fires or high-intensity surface fires—but each survives by sprouting from root crowns or by reseeding.

Chaparral.—This is perhaps the most flammable vegetation type in the United States and has its counterparts in many mediterranean-climate ecosystems around the world. It exhibits some of the most high-intensity fire behavior found anywhere. Inherent chemical, physical, and physiological properties of the vegetation contribute to its adaptation to fire and drought in a way that leads to an increased probability of high-intensity, fast-spreading, large fires occurring as the vegetation grows older (Philpot 1977). With high temperatures, low humidities, and high Santa Ana (foehn) winds typical of wildfire conditions in this type, flame lengths of more than 100 feet and spread rates of at least 500 feet per minute have been observed. The recurrence interval for large fires in California chaparral is 20 to 40 years (Byrne and others 1978) with large, severe fires tending to occur in brushfields older than 30 years (Green in Wright and Bailey 1982). At elevations above 4,000 feet on northern aspects, however, fire intervals may be from 50 to 100 years.

Sagebrush-Grass.—This vegetation covers at least 96 million acres in the Western United States, mostly below the pinyon-juniper zone (Wright and Bailey 1982). In presettlement times, maximum fire intervals in this community in northern Yellowstone National Park, WY, were every 32 to 70 years (Houston 1973). Fire behavior can vary from minimal burning conditions with flame lengths of 1 to 3 feet and fires that barely spread to 15- to 20-foot flame lengths and spread rates of more than 150 feet per minute.

Quaking Aspen.— In contrast to the previous two shrub types, aspen has been described as an "asbestos forest" in some areas because it does not burn readily even when surrounding coniferous forests will burn. Relative humidities below 35 percent, surface duff moisture less than 20 percent, and 4- to 15-mi/h winds are said to be required for successful burning (Wright and Bailey 1982); this can only take place during the occasional brief stretch of dry weather conditions between snowmelt and leaf flush in the spring or after leaf fall in the autumn. Flame lengths of 3 feet have been observed in living aspen and up to 30 feet in dead aspen stands (Wright and Bailey 1982). Studies are currently underway to resolve some of the difficulties in prescribed burning in western aspen forests and to increase our knowledge of fire effects in aspen (Brown and DeByle 1982). Fire frequencies of 50 to 100 years have been hypothesized by Hendricksen (1972) for aspen in the Colorado Rockies. This is supported by observations that, while aspen may live to 200 years in the absence of intense fire, stands tend to deteriorate after 80 to 100 years and be replaced by conifers (Loope 1971).

Fire's Effects in This Regime.—The dramatic impact of the interplay between fire frequency and intensity on the one hand and vegetation structure and reproductive strategies on the other is illustrated by recent work in southern California chaparral. Keeley and Zedler (1978) noted that chaparral is adapted to both short and long fire-free intervals, reflecting how unpredictable fire is in that environment. They suggest a model in which a short cycle (25 years) favors sprouting shrubs over those reproducing entirely from seed and a long fire cycle in which "sprouters" and "seeders" coexist. In the short cycle, there are fewer dead shrubs before the fire, more potential resprouts, less intense fires, lower fire-caused mortality of sprouting shrubs, and smaller openings for seedlings. In the long cycle (100 years), however, there are more dead shrubs before the fire, fewer potential resprouts, higher intensity fires, more fire-caused mortality of sprouting shrubs, and larger openings for seedlings. In the case of aspen, the species tends to be fairly short-lived, is susceptible to many diseases, and cannot survive or reproduce in the shade of competing conifers such as Douglas-fir (Loope 1971; Gruell and Loope 1974). Without regular fire, aspen does poorly, and recent fire suppression is thought to be a major factor in aspen decline.

Variable Regime: Frequent, Low-Intensity Surface Fires and Long-Return-Interval, Stand-Replacement Fires

Long-return-interval crown fires were part of the natural fire regime for many forest ecosystems in four major regions of North America: (1) the boreal forest of northern Canada and interior Alaska; (2) the Great Lakes forests; (3) the forests of the Pacific Northwest; and (4) most of the Rocky Mountain wilderness forests (Heinselman 1978, 1981; Franklin and Hemstrom 1981). In some areas, however, the regime varied between relatively frequent, low- to moderate-intensity surface fires and long-return-interval stand-replacement fires (including severe surface fires), depending on weather conditions and ignition factors on particular sites. When wind and other weather conditions are favorable for intense burning, the likelihood of crown fires depends on (1) the spacing of trees; (2) the quantity of crowns per unit area; (3) the amount and arrangement of surface fuels; and (4) how high the crown canopy is above the surface fuel heat source (Brown 1975). Such intense fires have occurred periodically at intervals between 100 and 300 years in lodgepole pine, western white pine (*Pinus monticola*), and western larch forests of the Rocky Mountains; in Douglas-fir and lodgepole pine forests in the Cascades (Fahnestock 1977); in black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), lodgepole pine, and aspen-birch forests of the boreal forest region as well as the Lake Superior region (Heinselman 1978, 1981, 1985). In the latter region, red and white pine sites had a regime of light to moderate surface fires at 20- to 40-year intervals combined with the long-interval crown fire regime.

Boreal Forest.—During presettlement times, the dominant fire regime in the main boreal forest regions of Canada and interior Alaska was apparently one of high-intensity short- to long-return-interval crown fires (or severe surface fires). These were large to very large in size (Heinselman 1981), often covering more than 25,000 acres and sometimes more than a million acres (Heinselman 1985). In the drier regions of northwestern Canada and interior Alaska, fire cycles probably averaged 50 to 100 years; by contrast, cycles of 100 to 300 years were found in eastern Canada, with its wetter climate, and near treeline in the open subarctic spruce-lichen woodlands. Some jack pine and lodgepole pine forests in western Canada have regimes that include medium-intensity surface fires at intervals of about 25 years that do not kill whole stands. All references to fire regimes in the boreal forest discussion above and Great Lakes forests discussion below rely largely on the extensive studies and summaries prepared by Miron Heinselman (1973, 1978, 1981, 1985).

Great Lakes Forests.—The presettlement Great Lakes forests had three distinct fire regimes: (1) jack pine and spruce-fir forests with very large stand-replacement crown fires or surface fires every 50 to 100 years in the west and 150 to 200 years in the east (such fires in Boundary Waters Canoe Area sometimes exceeded 250,000 acres in size); (2) red and white pine forests with combinations of moderate-intensity surface fires at 20- to 40-year intervals, and more intense crown fires at 150- to 300-year intervals; and (3) mixed aspen-birch-conifer forests with high-intensity surface or crown fires (while intervals are less sure here, spruce budworm outbreaks occurred every 40 to 70 years, creating tremendous fuel loads at those intervals).

Pacific Northwest Douglas-fir Forest.—The fire disturbance pattern in the Pacific Northwest generally is one of infrequent, stand-replacing crown fires that occur after intervals of several centuries (Franklin and Hemstrom 1981). While analysis of age structure and developmental history in this region is just beginning, it would appear that many Douglas-fir forests came in over a long regeneration period (more than 100 years) following one or more major fires that occurred about 500 years ago. Such major fire episodes seem to correlate with dry climatic conditions. Earlier authors felt the mere presence of Douglas-fir on a given site in the

Northwest was considered evidence of periodic timber-killing fire (Martin and others 1976) at frequencies of 50 to 400 years. The important regional characteristics noted by Franklin and Hemstrom (1981) were that in the Pacific Northwest trees grow very large and old; the forests recover slowly after a disturbance like fire, with canopy closure taking 40 years or more; and regeneration of trees after the fire may occur over a period of 100 years or more. More recent work has suggested that on drier sites more frequent fire and a patchier forest mosaic existed (Agee and Dunwiddie 1984).

Rocky Mountain Forests of Lodgepole Pine.—Fire regimes in the Rockies are extremely complex, reflecting the great variation in climate, topography, vegetation, and productivity of mountainous regions (Heinselman 1985). One aspect of the vegetative complexity is the wide ecological amplitude of lodgepole pine. Lodgepole is an extremely adaptable species; it seems to be a fire, edaphic, or topoedaphic climax species that occupies sites that are too dry, too wet, too cold, too infertile, or in some other way unsuited to other species (Wright and Bailey 1982). In some areas it occurs in even-aged stands resulting from periodic stand-replacing fires, while on other sites it occurs with multiple ages, sizes, densities, and height classes, interspersed with small even-aged stands. The two dominant regimes in most presettlement wilderness forests were: (1) long-return-interval crown fires (perhaps 100 to 300 years) in the continuous forests of lodgepole pine mixed with spruce and fir, and (2) shorter return-interval (5 to 60 years) low- to moderate-intensity surface fires in the lower elevation Douglas-fir, aspen, and ponderosa pine stands, grassy parklands, and in adjacent open lodgepole pine stands (Heinselman 1978).

The major vegetation pattern found in lodgepole pine today was caused by stand-replacement fires, although many uneven-aged lodgepole pine stands result from lower intensity surface fires (Brown 1975). Most individual fires were low-intensity, creeping, surface fires, but most acreage was burned by the occasional high-intensity crown fires that occurred during severely dry and windy weather (Lotan and others 1985). Average intervals between crown fires varied from 60 to 400 years or more, although lodgepole pine has a lifespan that varies with site and geographic locations from 80 to 400 years, and the species tends to be eliminated from sites having very long intervals between fires (Antos 1977).

In Yellowstone National Park and adjacent wilderness, Despain and Sellers (1977), Romme (1980, 1982), and Romme and Knight (1981) concluded that most stands will not sustain crown fires until they develop a significant understory component of Engelmann spruce (*Picea engelmannii*) and subalpine fir 300 years or more after the previous fire. Sizes of recent such fires have been about 1,000 to 8,000 acres (Heinselman 1985). Large areas of lodgepole pine have been found by Despain (1983) with almost no spruce-fir component; he concludes these are essentially self-perpetuating climax lodgepole pine stands that often exceed 300 to 400 years of age with no evidence of fire since establishment. Similar stands occur in the Sierra Nevada (Parker in press).

Most fires in lodgepole pine are either very slow and smouldering or rapidly moving, intense crown fires (Lotan and others 1985). In large summer wildfires, both high- and low-intensity fire behavior can be triggered by diurnal weather changes; with winds down at night, the tendency to crowning behavior decreases and the fire creeps and smoulders in erratic fashion, resulting in a thinned stand with spotty exposure of mineral soil (Muraro 1971). By the following day, however, as temperatures and winds increase, surface fires increase in intensity until crowning again becomes more general, and, depending on fuels and forest structure factors noted earlier, may become very severe with not only needles, but branches up to one-half inch in diameter consumed, as well as some involvement of larger boles. Such variations have tremendous impact on fire effects. These effects range from (a) a thinned stand, or (b) a very low density stand of lodgepole pine, to (c) an extremely dense stand and a dead snag forest.

Fire's Effects in This Regime.—The intensity and frequency of fires in lodgepole pine largely determine establishment of seedlings and subsequent development of stand density, age structure, and species composition (Brown 1975; Kilgore 1981; Lotan and others 1985). Higher intensity fires tend to favor lodgepole pine over such species as Douglas-fir and western larch, depending on local winds, topography, and fuels. In certain instances, frequent fire may prevent lodgepole pine from invading aspen where the two grow in mixed stands, except where intense burns kill aspen roots (Brown 1975). The timing of the fire also makes a difference. Burns preceding a good larch seed crop tend to favor larch. It is harder to predict species composition of a mixed conifer forest involving lodgepole after a low-intensity fire.

Such mortality factors as the needle miner, bark beetle epidemics, mistletoe infestations, and death of suppressed trees in the understory of a dense forest all have impacts on species composition, successional pattern, vegetation mosaic, and fuel accumulations. These factors augment buildup of surface fuels that increase the probability of large, high-intensity surface fires (Brown 1975).

While fire effects in such a complex forest community and region are also many and complex, one conclusion consistently reached by scientists and resource managers working in the Northern Rocky Mountains is that there are few areas in which climax forests of spruce (*Picea* sp.), fir (*Abies* sp.), hemlock (*Tsuga* sp.), and western redcedar (*Thuja plicata*) have been allowed to develop. Instead, fire—whether frequent and of low intensity or less frequent and of higher intensity—has repeatedly favored the development of stands of intolerant, fire-dependent species such as lodgepole pine, aspen, western larch, western white pine, ponderosa pine, and Douglas-fir (Wellner 1970; Habeck and Mutch 1973; Weaver 1974; Arno 1980).

Very Long-Return-Interval, Stand-Replacement Fires

Stand-replacement fires at mean return intervals longer than 300 years are characteristic of ecosystems in which shade-tolerant species are dominant; these include the spruces, true firs, western redcedar, and western hemlock. These species tend to occur on moist environments. In discussing such long-rotation types, Habeck (1985) notes they do not exhibit the same level of midsummer dryness found in short-fire-interval vegetation types and thus only occasionally burn extensively. When this does occur, the fire may remain a low-intensity burn, or it can sometimes become a high-intensity stand-replacement burn (Habeck 1976; Fahnestock 1976; Despain and Sellers 1977; Davis and others 1980), depending on climatic and fuel factors.

Spruce-Fir Forest.—These forests are so damp they seldom burn (Weaver 1974) except during extreme droughts. During those periods, fires burn very intensely through these forests because their highly flammable green limbs are close to the ground. In the Northern Rocky Mountains generally, Arno (1980) reported that moist subalpine fir-Engelmann spruce forests had fire-free intervals of 150 years or more, and that when fire did come, it was usually a high-intensity, stand-replacing fire. Intense burning in 350-year-old spruce-fir forests in Yellowstone National Park was apparently related to such forest structural factors as compact growth form, with numerous small branches close together, lower branches that did not self-prune, a fruticose lichen that had accumulated on the branches, and heavy accumulations of duff and rotten wood (Despain and Sellers 1977).

Cedar-Hemlock Forest.—Relatively little information on fire frequency or intensity is available for either of the extremely moist forests: (1) western hemlock-western redcedar of the Northern Rocky Mountains, and (2) Sitka spruce (*Picea sitchensis*)-hemlock-redcedar of the Pacific coastal forests. Hemlock-redcedar forests generally occur on sites with the dampest climate found in the Rocky Mountains, but extreme summer drought from time to time has set the stage for occasional, spectacular crown fires (Arno 1980). The most recent large conflagration was the 1967 Sundance Fire that burned 56,000 acres in northern Idaho (Anderson 1968). Earlier, high-intensity crown fires burned several million acres in 1889, 1910, 1919, 1926, and 1934, much of it in the hemlock and redcedar forests of northern Idaho (Arno 1980).

Natural fire cycles of western redcedar forests in the Selway-Bitterroot Wilderness of Idaho and Montana are from 100 to 400 years (Habeck 1985). "The oldest forest communities (over 400 years old), those burned least often, are those dominated by redcedar on the moist streamsides and in ravines" (Habeck 1976). In recent studies in northern Idaho, the mean fire-free interval for streamside western redcedar habitat types was greater than 200 years and fire intensities were low (Arno and Davis 1980). Some of the adjacent uplands in this zone (predominantly south and west exposures), however, are predisposed to spectacular crown fires at intervals of 50 to 150 years by extreme summer droughts that occur every few years, high accumulations of fuels in these productive forests, lightning, and high winds during dry periods (Arno and Davis 1980; Wright and Bailey 1982). Lotan and others (1981) hypothesized that the wettest forest in this type may burn at intervals of 500 years or longer; Fahnestock and Agee (1983) suggested a fire-return interval of more than 2,000 years for this type based on forest survey data.

True Fir Forests.—High-intensity, stand-replacement fires at intervals of about 150 years were apparently more prevalent than surface fires in grand fir (*Abies grandis*) habitat types (potential climax) of Swan Valley, MT (Antos 1977). Illustrating the extremes of true fir fire history, in the Blue Mountains of eastern Oregon, low-intensity, frequent surface fires were the rule in grand fir habitat types (Hall 1976). By contrast, a natural fire rotation averaging 434 years over the past 1,000 years was found for true fir forests of Mount Rainier National Park, WA (Hemstrom and Franklin 1982). A fire-free interval of about 500 years has also been estimated for the Pacific silver fir (*Abies amabilis*) zone, the most extensive forest zone in the Olympic Mountains of Washington (Wright and Bailey 1982).

Fire's Effects in This Regime.—In general, the shade-tolerant species represented by this fire regime are the species most susceptible to damage and mortality from fire (Lotan and others 1981); in effect, these species depend on an absence of fire. The longer a forest stand goes without fire, the more these shade-tolerant, climax species are favored over fire-dependent seral species. When fire occurs, the trend is reversed and lodgepole pine, Douglas-fir, and the spruces dominate for a period of time.

Broad Summaries of Fire Effects

Fire's Effects on Wildlife Populations and Habitats.—With the great differences in fire frequencies and intensities found in these six fire regimes and many vegetative types, it is reasonable to expect that fire would have a variety of impacts on the broad array of wildlife species found in various ecosystems (Kilgore 1976). More than 450 publications dealing with species-specific responses of birds, animals, and invertebrates to fires of varying intensities have been summarized by Lyon and others (1978), Bendell (1974), Wright and Bailey (1982), and Kramp and others (1983). Australian wildlife response to fire was summarized by Gill and others (1981), and a brief review of worldwide literature has been undertaken by Chandler and others (1983). In reviewing the results presented in more than 290 publications, mostly between 1960 and 1972, Bendell (1974) concluded that it is difficult to generalize about the effects of fire on birds and mammals. While a few researchers believe wildfire is extremely destructive of wildlife, many feel direct mortality is negligible.

Behavioral responses of birds and animals to fire appear to run the gamut from (1) wild panic for certain small rodents, such as mice, to (2) calm movement away from the fire for larger, more mobile animals like moose, caribou, swans, and raccoon, to (3) a positive movement toward the fire by many North American, African, and Australian birds and animals, including large African animals, insectivorous birds, quail, turkeys, birds of prey, and several primates (Komarek 1969; Lyon and others 1978; Chandler and others 1983). The extreme example of positive behavior response to fire may be that of the firehawk, a predatory and scavenging bird from Australia that deliberately sets fire to grass and brushland to assist its scavenging. Lockwood (1962) reported that "I have seen a hawk pick up a smouldering stick in its claws and drop it in a fresh patch of dry grass half-a-mile away, then wait with its mates for the mad exodus of scorched and frightened rodents and reptiles. When that area was burnt out the process was repeated elsewhere."

This spectrum of behavioral responses of wildlife to fire is paralleled by a spectrum of responses to the far more important changes in wildlife habitat—food, cover, and microclimate. In a state-of-knowledge review of the effects of fire on fauna, Lyon and others (1978) concluded that: (1) While fire may temporarily displace species dependent on late stages of plant community development, such as caribou, marten, wolverine, and fisher; (2) there is a remarkable stability of species numbers and populations of smaller birds and animals following fire; and (3) in general, larger animals such as moose, deer, elk, black bear, and grouse increase in numbers after fire.

In terms of their response to fire, wildlife have been grouped into one of four categories (Kramp and others 1983):

1. Fire-intolerant species, like the hermit thrush, spotted owl, and white-footed mouse, decrease in abundance after fire.
2. Fire-impervious species, like the Steller's jay, Townsend's solitaire, and pronghorn, are unaffected by burning.
3. Fire-adapted species, like the bobwhite quail (Stoddard 1935), western wood pewee, junco, elk, coyote, and perhaps the grizzly bear (Zager and others 1980; Madel 1982; Craighead and others 1982), are associated with habitat that is characterized by recurring fires of various intensities, but they are not fire-dependent.
4. Fire-dependent species, like the Kirtland's warbler and perhaps the California condor (Wright and Bailey 1982) are associated with fire-dependent and fire-adapted plant communities, and require fire to provide some aspect of their habitat.

Considerable variation in wildlife population response to habitat changes caused by fire may be related to differences in: intensity, severity, and duration of the fire; the season of burning; the vegetation type and animal species involved; and whether we are considering short-term or longer term effects.

The influence of fire on wildlife habitat can be summarized with several broad principles (Kramp and others 1983): (1) Quantity and quality of browse for herbivores often increase immediately after fire; (2) fire increases quantity or availability of berries and seeds for birds and mammals; (3) in boreal forests, fire tends to eliminate some forage plants associated with older stands of timber, such as arboreal lichens; (4) fires may increase populations of surface and wood-boring insects that are important to quail, woodpeckers, and other insectivorous birds, but decrease populations of other pest insects and animal parasites; (5) fire impacts cover by changing the scale and pattern of vegetation mosaics as well as "edge" and diversity of related wildlife habitat through frequency, intensity, and size of burn; and (6) fire impacts succession and alters plant species composition and vegetation structure in ways that favor some wildlife species and not others.

Fire's Effects on Insects and Diseases.—A bibliographic data base of 175 publications has recently been compiled that deals with fire's effects on insects and diseases and their habitats in the Northern Rocky Mountains. A brief summary of that bibliography (Barrett 1985) concludes that relatively little quantitative research has been devoted to interactions between fire, insects, and diseases, although there has been considerable speculation about possible ecological relationships (Miller and Keen 1960; Roe and Amman 1970; Alexander and Hawksworth 1976; Parmeter 1977; Barrett 1985). Many fire ecology publications focus on vegetative succession with brief discussion of possible effects of fire or suppression of fire on habitats of insects and diseases. Insect and disease research in general has concentrated on a few economically important species on lands managed intensively for timber, including the mountain pine beetle (*Dendroctonus ponderosae*), spruce budworm (*Choristoneura occidentalis*), and dwarf mistletoe (*Arceuthobium* spp.). Little work has been done on lands managed as wilderness or parks.

Insects and diseases are important in modifying the age structure of many forests and in turn the frequency and intensity of subsequent fires (Brown 1975). Conversely, "fire or the lack of it regulates the total vegetative mosaic, and the age structure of individual forest stands within it" (Wright and Heinselman 1973) which, in turn, influence insect populations. For example, in the absence of fire in the Northern Rockies, mountain pine beetle activity leads to replacement of lodgepole pine by Douglas-fir at lower elevations and by subalpine fir and spruce at higher elevations. When extensive stands of lodgepole pine reach maturity, insect outbreaks create fuel concentrations that make large-scale fires possible. These fires, of course, result in new stands of the host tree, temporarily free from insect attack.

Presettlement fire played an important role in maintaining more open stands of ponderosa pine, larch, Douglas-fir, and true firs that were less susceptible to outbreaks of western spruce budworm. But decades of fire suppression have now allowed development of dense, multistoried stands of shade-tolerant host species preferred by the budworm (primarily the true firs and Douglas-fir). Ideal budworm habitat involves (1) shade-tolerant conifers; (2) dense, overcrowded stands, with much crown contact; (3) multistoried stands; (4) stressed trees as opposed to vigorous trees; (5) older mature stands; (6) warm, dry locations such as south-facing aspects on moderately steep slopes at lower elevations; and (7) stands with continuity of susceptible host type in adjacent or surrounding areas (Carlson and others 1985). Clearly, low-intensity, frequent fires in these regimes would have reduced many of these characteristics and in so doing would have held down habitat available for budworms. Fire exclusion, on the other hand, has directly supported development of sizable acreages of ideal habitat in such western wildernesses as the Selway-Bitterroot, Bob Marshall, Scapegoat, Anaconda-Pintler, Spanish Peaks, and Welcome Creek (Carlson and others 1985).

The relationship between fire and disease is complicated both by the variability of fire intensity and frequency and by the complexity of interactions between fire and disease. In the absence of fire, numbers of trees infected, intensity of infection, and degree of damage increase with age of trees or stands and size of trees. The rate of spread through multistoried stands is also more rapid than through single-storied stands (Parmeter 1978).

As one example, intense fires tend to have a sanitizing effect on mistletoe-infected stands, allowing young trees to develop without mistletoe raining down from above; partial burns create ideal conditions for rapid spread of mistletoe in even young stands (Alexander and Hawksworth 1976). Mistletoe, on the other hand, kills and stunts trees and causes spike tops and witches' brooms that modify vertical structure of the forest, providing "ladders" for fire to ascend and consume tree crowns. This obviously increases fire hazard, flammability, and fire intensity. Fire may encourage spread of the mistletoe parasite by conversion of nonsusceptible climax spruce-fir forests to mistletoe-susceptible nearly pure stands of lodgepole pine (Alexander and Hawksworth 1976). In some areas of the Northern Rockies, fire suppression has allowed mistletoe-infected Douglas-fir to increase in stands that were formerly dominated by uninfected ponderosa pine.

Prescribed burning on pine plantations in the South reduced pine mortality and total infection by *Heterobasidion annosum* (*Fomes annosus*) root rot (Froelich and others 1978). The impacts of fire on the fungus were greatest where the disease was most serious.

One of the first concentrated efforts at a more detailed understanding of fire-insect-disease interactions is in climax lodgepole pine stands with sparse fuels in south-central Oregon (Gara and others 1985). Initial work has led to the conclusion that mountain pine beetle epidemics create scattered downed fuels that increase likelihood of low-intensity surface fires that lead to root damage and basal fire scars. The damaged roots become infected, experience fungal decay, and in time a succession of fungal organisms (*Poria* spp.) invade and decay the bole. The mountain pine beetle, in turn, preferentially lands upon these trees and kills more scarred trees than unscarred trees. Beetle activity apparently leads to spatially clumped kill patterns and hence spatially clumped seedling establishment and mosaic patterns, in part related to aggregating behavior of beetles in response to pheromones (Stuart 1983). Past fire history has included a stand-replacement fire in 1840 and a low-intensity surface fire in 1898; such intensity differences have a strong bearing on stand structure, mosaic pattern size, and tree vigor, all of which impact susceptibility to beetle attack and fire relationships. Many other complex and interesting interactions are being investigated in what appears to be a highly productive line of study for future understanding of insect/disease/fire relationships in wilderness ecosystems.

It appears that human efforts to decrease fire frequency often lead to conditions favoring growth of forest insects or disease organisms. Such growth in turn affects forest structure and fuel buildup in a way that enhances the likelihood that the forest will burn with greater intensity than would have been the case otherwise.

Fire's Effects on Nutrient Cycles.— Mineral absorption by plants is a constant drain upon the soil (Behan 1970). A sizable quantity of minerals is incorporated in living and dead tree trunks and retained for many years, while needles and small twigs are dropped annually as litter. Minerals are gradually returned to the soil from such litter by leaching and the slow action of decomposer organisms. But, in many ecosystems, fire plays a major role in returning various mineral nutrients to the soil.

The immediate effect of fire is the conversion of organic matter to ash and charred materials (Boerner 1982), with some loss to the atmosphere by volatilization and some material remaining incompletely burned. Of those materials that are burned, any nutrients not volatilized or washed from the soil will be available for use by vegetation (Boerner 1982). While there is no quantitative model to predict transformation of elements and subsequent soil chemical changes from fire, there is general acceptance that available phosphorus, potassium, calcium, and magnesium levels increase following burning (Hare 1961; St. John and Rundel 1976; Wells and others 1979). It appears that total nitrogen decreases immediately after burning, but there tends to be an immediate increase in soluble or available nitrogen and an increase in total nitrogen over time, in part because of nitrogen fixation (St. John and Rundel 1976; Wells and others 1979). Conflicting research findings about the impact of fire on nitrogen result in part from failure to make this distinction as well as failure to note differences in fuel characteristics and fire intensities.

Overall, low-intensity surface fires facilitate cycling of nutrients and generally do not increase soil erosion, while high-intensity fires volatilize large amounts of nitrogen, disrupt soil structure, and may induce water repellency and erosion (Wells and others 1979). In natural ecosystems, rates and pathways of nutrient cycling are influenced by fire frequency and intensity. "In the absence of fire, nutrient cycles . . . can be partially or severely blocked by incomplete decomposition of biomass" (Wright and Heinselman 1973). Without natural fire, there tends to be an accumulation of fuels in many systems that leads to the likelihood of even higher intensity fires, with possible adverse consequences on soil nutrients.

Fire's Effects on Diversity and Stability.—There is considerable disagreement about how to measure these basic and fundamental concepts; it is thus difficult to compare the effects of fire on these factors in wilderness ecosystems. Vogl (1970) noted that "If stability is defined as the ability to resist change, then . . . vegetative cycles maintained and driven by fire must be considered to be stable." As such, lodgepole pine communities would be considered very stable, because fires in such seral communities result in a replacement forest of similar structure to that originally found there, while fire in a climax spruce-fir forest results in extreme changes (Brown 1975). In such vegetation where large crown fires are typical, individual patches of a mosaic may cover thousands of acres in dynamic patterns, yet the mosaic as a whole changes little over time. "... the patches—like the pieces of a kaleidoscope—are periodically rearranged by fire and succession" (Heinselman 1978).

While earlier concepts of climax communities would have defined them as somehow inherently more diverse and stable than pioneer communities that follow fire, such undisturbed natural systems apparently did not exist in the real world; fire interrupts such successional trends at intervals related to the fire regime involved. Disturbance by fire or other factors can either speed up succession or set it back, depending on which species of a stand are attacked by wind, fire, insects, or disease. It appears that the ever-changing, fire-created mix of successional stages, communities, and stand ages in the vegetation mosaic of most wilderness forests is somehow essential to the stability of the system as a whole (Loucks 1970; Wright and Heinselman 1973b; Heinselman 1978).

Some different points of view recently presented in the ecological literature concerning stability, diversity, and resilience (Holling 1973; May 1973; Botkin and Sobel 1975; Orians 1975; Westman 1978) have been reviewed elsewhere (Kilgore 1981). Two main points were that (1) a static stability concept, borrowed from classical physics, may be inappropriate for the analysis of ecosystems because such natural undisturbed ecosystems "... are likely to be continually in a transient state" (Holling 1973); and (2) population stability in the natural world is not uniformly associated with trophic complexity and faunal and floral diversity. On the contrary, May (1973) noted that a number of natural monocultures, such as *Spartina* marsh grass, are very stable, and that instability comes not from simplicity, but from unnaturalness. He even contended that as a mathematical generality, increasing diversity and complexity enhance community instability. But he also agreed that we need much better understanding of principles that govern natural associations of plants and animals, something that can be gained primarily from studies of pristine ecosystems in wildernesses and National Parks.

ADOPTION OF RESEARCH RESULTS BY MANAGERS

Fire management on wilderness units of National Forest and National Park lands has come a long way in the past two decades. Just 17 years ago, in 1968, largely based on ecological research findings of the past 50 years, the National Park Service modified its policy of immediate suppression of all fires, which had been standard practice since the late 1800's. The Forest Service also began allowing lightning-caused fires to play a more natural role in wilderness in 1970, and in 1971 exceptions to the 10 a.m. (total suppression) policy were authorized when approved by the Chief of the Forest Service. This gradual revision of policy (see Kilgore 1976, 1982) culminated in early 1985 in a policy revision whereby Forest Service-ignited prescribed fires are allowed in wilderness under certain conditions. The broad research basis for such changes in policy and programs was reviewed earlier (Kilgore 1976).

One of the important aspects of the new Forest Service policy is use of prescribed fire to reduce unnatural buildups of fuels when this is necessary to meet the two objectives of fire management in wilderness. These two objectives are to (1) "permit lightning-caused fires to play, as nearly as possible, their natural ecological role within wilderness"; and to (2) "reduce, to an acceptable level, the risks and consequences of wildfire within wilderness or escaping from wilderness." (USDA 1985). Thus, Forest Service personnel will only ignite fires where—because of past fire suppression—lightning-caused fires alone cannot achieve wilderness management objectives. Thus before using prescribed fire, wilderness managers need to be sure the fire danger in a given area, as a result of fire suppression, is greater than would have existed had fire been allowed to occur naturally during the past 50 to 70 years. As such, criteria are needed to aid managers in judging when and where prescribed fire would be appropriate.

Since the early 1970's, fire management programs in the United States have expanded rapidly in National Parks and formally designated National Forest wilderness areas (Kilgore 1982). Similar programs are being considered for national parks in Canada (Lopoukhine 1985) and conservation reserves in Australia (Good 1981). Major programs of research on ecological effects of fire in South Africa (Huntley 1978) seem to provide the scientific basis for similar programs in national parks and reserves in that country.

By 1983, sufficient interest in programs involving natural fires and prescribed fires in wilderness and parks had developed that an entire symposium and workshop was held, in Missoula, MT, to discuss various implications of wilderness fire research and policy. More than 700 participants attended this 4-day session from Australia, Sweden, and all parts of the United States and Canada.

Success Stories

Lightning-caused fires are allowed to burn on 7 million designated acres in 16 areas managed by the National Park Service and on 9 million designated acres in 18 National Forest Wildernesses. Since the beginning of these programs, more than 1,200 lightning-caused fires have been allowed to burn about 190,000 acres of National Parks and National Forests. In addition, more than 840 planned prescribed burns were ignited in 26 national park areas covering some 180,000 acres (Kilgore 1982). Benchmark wilderness fire management programs are found in Sequoia-Kings Canyon, Yosemite, Everglades, Yellowstone, and Grand Teton National Parks and the Selway-Bitterroot, Gila, and Teton Wildernesses of the National Forest System.

Sequoia-Kings Canyon and Yosemite National Parks.—Early research by Weaver (1943) and Biswell (1967) in ponderosa pine forests provided important background understanding of the role of fire in the frequent, low-intensity fire regime vegetation. Subsequent research publications by Hartesveldt (1964), Biswell and others (1966, 1968), and Park Service scientists (Kilgore 1973a, Parsons 1978) pointed out the threat to mature sequoias by continued suppression of all fires. These studies combined with the 1963 Leopold Report led to a three-part fire management program, the first of its kind, which:

1. Allowed lightning-caused fires to burn under prescribed conditions in designated areas where previous suppression had not had major impacts on fuel loading or plant succession/forest structure and when such fires do not threaten human life or property.
2. Used prescribed fires where unnaturally high fuel loads have accumulated following years of suppression and along boundaries.
3. Continued aggressive suppression of wildfires in developed areas where human life and property damage are major concerns.

To provide the additional information needed to support such a program, emphasis was given to studies of the role of fire in both high-elevation California red fir/lodgepole pine forests and low-elevation chaparral as well as the better known, lower elevation giant sequoia-mixed conifer forests. Research publications by National Park Service and Forest Service scientists (Agee, Kilgore, Parsons, Sando, and van Wagtendonk) and university scientists (Biswell, Bonnicksen and Stone, Hartesveldt, Harvey, and Rundel) provided a strong data base that was used by resource managers (Bancroft, Botti, Briggs, Nichols, Partin, and Riegelhuth) in preparing fire management plans for these parks (Bancroft and Partin 1979; Botti 1979). More than 87 percent of these two parks (1.4 million acres out of 1.6 million acres total) is included in natural fire zones, within which some 450 lightning fires have been allowed to burn nearly 40,000 acres in the first 15 years of the program (Kilgore 1982). In addition, nearly 150 prescribed fires, covering another 40,000 acres, have been ignited by National Park Service personnel. By nearly all standards, these programs are perceived to be a success, but recent studies have raised questions about whether more specific vegetation objectives are needed to achieve presettlement forest structure prior to further use of prescribed burning (Bonnicksen and Stone 1982a,b; Bonnicksen 1985; Parsons and others 1986). Such additional studies may help improve the quality of fire management in these parks.

Selway-Bitterroot Wilderness.—The White Cap Fire Management Area in the Selway-Bitterroot Wilderness in Idaho was the first approved exception to the Forest Service 10 a.m. (total suppression) policy. This exception was approved in 1972. In a pioneering joint research and management effort, fire management prescriptions were written for each vegetative management zone of the 100-mi^2 area (Mutch 1974). Special guidelines were developed by Forest Service researchers and managers for planning and inventory procedures (Aldrich and Mutch 1973). Other research support came from Habeck's studies of fire history, vegetation, and fuels in the Selway-Bitterroot (Habeck 1972, 1976).

The first major test of the White Cap plan was the 1,200-acre Fitz Creek Fire in 1973 (Mutch 1974). Although the fire spotted outside the approved fire management area and had to be suppressed on that side, the experiment was successful and led the way toward incorporating fire management considerations into wilderness planning generally in the Forest Service. Between 1974 and 1979, additional fire management plans were developed for various units of the Selway-Bitterroot Wilderness. The Independence Fire of 1979 burned more than 16,300 acres during a 3-month period, the largest fire allowed to burn under a natural fire program by any agency (Keown 1980, 1985a). By 1982, more than 1 million acres of the Selway-Bitterroot Wilderness were covered by plans that allow lightning-caused fires to play a more natural role. During the first 10 years of the program, 76 lightning fires have been allowed to burn nearly 39,000 acres (Kilgore 1982).

Grand Teton and Yellowstone National Parks and the Teton Wilderness.—Natural fire management programs on the Grand Teton and Yellowstone National Parks in Wyoming began in 1972. During the first decade of this program, more than 130 lightning fires were allowed to burn more than 38,000 acres. Among these were 13 large fires ranging from 160 to 7,400 acres in size (Kilgore 1982).

Studies of fire history and fire effects on various aspects of different ecosystems by Taylor (1969), Houston (1973), Loope and Gruell (1973), Sellers and Despain (1976), Despain (1982), and Romme (1982) served as the site-specific data base to support fire management plans for these areas. This basic information was extremely important to National Park Service managers in 1974 when the Waterfall Canyon Fire attracted much public attention to the whole concept of allowing lightning fires to burn in Parks and Wildernesses. This 3,500-acre fire also stimulated controversy about impacts of smoke on both National Park visitors and nearby communities. Air quality concerns must be met through smoke management criteria in current fire management plans; past and future research and monitoring can also play important roles in meeting this need (Ferry and others 1985).

One of the largest natural fire areas in the United States became operational in 1982 with approval of the revised Teton Wilderness Plan. Wilderness segments of Yellowstone and Grand Teton National Parks are coordinated in a more than 4-million-acre prescribed natural fire program with designated natural fire areas in the adjacent National Forest System Teton, Washakie, North Absaroka, and Absaroka-Beartooth Wildernesses (Kilgore 1982). Fire on National Park lands is allowed to cross the boundary onto National Forest lands, and fires on any of the forest wildernesses would be allowed to cross into Yellowstone and Grand Teton National Parks. While there has not yet been a test of how this interagency fire management concept will work, such opportunities will present themselves in the future. Agency researchers, both biological and sociological, would do well to help monitor the results of any such fires and the associated public reactions.

Everglades National Park.—The earliest exception to the total fire suppression policy in National Park Service areas was Everglades in Florida, where in 1951 Research Biologist Dr. William Robertson, Jr., began a study of the role fire plays in maintaining south Florida slash pine forest (Robertson 1953; Kilgore 1976). This work was followed in 1958 by experimental research into prescribed burning as a means of controlling the hardwoods. Other scientists found that fire was also essential to maintaining stability of saw grass glades. As mentioned earlier, the Southeast had been far ahead of the rest of the country in recognizing the major changes brought about by removal of the fire process, particularly from their fast-growing pine ecosystems. The primary research at Everglades that supported the management decision to continue prescribed fire to maintain pineland forest was that of Robertson (1953 and his long-term unpublished study, cited in Taylor and Herndon 1981), Hofstetter and Parsons (1975), and Craighead (1971, 1974).

Remaining Opportunities

Despite these successes, there are also many areas for improvement. One prime example would seem to be the Boundary Waters Canoe Area (BWCA) of Minnesota. No place in the country has a better fire history record than the BWCA as a result of the truly remarkable studies of Heinselman (1973) augmented by those of Swain (1973). Plans were made in 1976 for introducing random ignition prescribed fires within the BWCA on a pilot basis, but apparently these were never implemented because of expressed need for more planning. Two problems that Alexander and Dubé (1983) noted as being unique to using fire in northern ecosystems are lack of defensible boundaries and the typical high-intensity crown fires.

Better Use of Fire History Data.—Another important opportunity exists for wilderness and park managers to make better use of fire history data and historic vegetation patterns prior to developing fire management plans for their unit. Experiences on two recent well-known prescribed fires—Mack Lake and Ouzel (see Kilgore 1982)—led to the conclusion that had the managers in charge of those fires been aware of specific past fire history in those two areas, they each could have made far better judgments and saved major costs (and perhaps a human life in one instance).

Better Use of Fire Weather Data.—Another opportunity exists for managers to make better use of fire weather forecasts and related burning indices. Postburn reviews of three prescribed fires (Mack Lake, Ouzel, and Seney, in Kilgore 1982) indicate that some of the problems encountered could have been ameliorated by more effective use of past weather records through computerized programs like RXWTHR and RXBURN (Bradshaw and Fischer 1981) and more effective use of related burning indices through the National Fire-Danger Rating System (Deeming and others 1977).

Incorporation of Research Results Into Management Practices.—In some instances, research results are not being incorporated into management practices quickly enough—both in the United States and elsewhere. Considerable insight into the role of fire in various ecosystems in Australia, Africa, and Canada, for example, is available through reporting of research findings in recent books, symposia, and other publications (Rowe and Scotter 1973; Huntley 1978; Schirge and Penderis 1978; Alexander 1978, 1979, 1980; Tande 1979; Hawkes 1980; Gill and others 1981; Alexander and Dubé 1983; Wein and MacLean 1983). And yet, no natural fire management plans or programs seem close to implementation in national parks or wilderness units in these countries. Even in well-established programs, new research findings about impacts of fire will be useful in reevaluating current fire management practices. Agency management personnel must always remain flexible enough to carefully consider new information. And researchers must be willing to define the limits of applicability of their data so as not to redirect policy based on flimsy research evidence. The overall goal must always be to restore natural processes and natural conditions to national parks and wilderness units, rather than a stubborn commitment to particular past techniques of achieving that goal.

CONFLICTING KNOWLEDGE AND UNRESOLVED ISSUES

In my judgment, the following are several of the key unresolved issues in wilderness fire management.

How Much Impact has Fire Suppression Had on Fire Regimes and Ecosystems?

The absence of fire for the past 50 to 100 years may have resulted in two primary changes in a forest or other vegetation that should be of concern to the wilderness manager: (1) It may have allowed accumulation of unnatural levels of fuels, or (2) it may have caused modification of species composition, age structure, or of horizontal or vertical forest structure beyond the range found in presettlement forests (Kilgore 1981).

Unnatural Fuels.—The question of unnatural fuel levels was addressed recently by Habeck (1985), van Wagtendonk (1985), and Brown (1985). In short-fire-return-interval ecosystems, where fires occur every 10 years or so, lack of fire for a 50- to 100-year suppression period could allow accumulation of fuels to an unnatural level. By contrast, in long-fire-return-interval ecosystems, where natural fire cycles range from 100 to 500 years or more, fire suppression for the past 50 to 80 years has probably not affected these ecosystems greatly. Brown (1985) wonders if the whole concept of whether fuel buildups are natural or unnatural is important. He urges, instead, that we focus our attention on forest structure—and specifically ". . . maintaining a natural balance of successional stages."

Relatively few studies have been undertaken specifically on the question of unnatural buildup of fuels as a result of fire suppression. The prime fire regime for such studies would be the frequent, low-intensity regime. The few studies to date have been carried out in the sequoia-mixed conifer forest (Parsons 1978; Parsons and DeBenedetti 1979).

Changes in Forest Structure.—Forest structure is often divided into four conceptual aspects: age structure, species composition, horizontal structure or mosaic pattern, and vertical structure or fuel ladders (Kilgore 1981). Each of these aspects can be modified by fire exclusion. The same three authors who discussed fuel accumulation at the Wilderness Fire Symposium also addressed the question of changes in forest structure as a result of fire suppression. In the frequent, low-intensity fire regime, ack of fire has allowed shifts in species composition from sun-loving pine to more shade-tolerant true fir and related changes in mosaic patterns and vertical fuel ladders (Kilgore and Sando 1975; Bonnicksen and Stone 1982b; van Wagtendonk 1985) as well as changes in age composition of the various mixed conifer species (Kilgore and Taylor 1979; Parsons and DeBenedetti 1979). Brown (1985) suggests, "Mosaics of successional stages offer a more fundamental and reliable basis for determining naturalness than do fuel buildups." Such changes in fuel and forest structure may not be apparent in the long-return-interval fire regimes (Habeck 1985). One might reason, however, that stopping mosaic recycling by low-intensity understory burning for 60 years in an ecosystem with both frequent low-intensity fires and a 150-year cycle of stand-replacing fire does disrupt the vegetation mosaic, especially the proportion of young successional communities.

The relatively few studies of changes in forest structure as a result of fire suppression have been carried out in ponderosa pine forest (Weaver 1943, 1974; Cooper 1960; Lunan and Habeck 1973), sequoia-mixed conifer forest (Kilgore 1973a; Vankat and Major 1978; Kilgore and Taylor 1979; Parsons and DeBenedetti 1979; Bonnicksen and Stone 1982b), and other montane forests (West 1969). Major structural changes because of fire suppression noted in these studies have been: (1) a large increase in the younger age classes of pine in ponderosa pine habitat types (potential climax) and shade-tolerant white fir (in sequoia-mixed conifer forests); (2) survival of aplings beneath mature trees (in ponderosa pine forests) and one or more vertical layers or tiers of white fir beneath the overstory canopy of sequoia and pine (in sequoia-mixed conifer forests) providing ladder fuels that can lead to high-intensity crown fires; (3) many more rees per acre, particularly young shade-tolerant saplings; (4) a blending of what had been discrete patchy units into a more uniform forest, with more uniform burning intensities, gradually destroying the identity of individual even-aged groups or aggregations found in presettlement times.

Work is just beginning on the impact of fire exclusion on other vegetation types, particularly those Rocky Mountain forests involving mixtures of lodgepole pine, Douglas-fir, ponderosa pine, and larch in which a variable regime of frequent low-intensity surface fires alternates with long-return-interval, stand-replacing fires. The question to be answered here, is: has suppression of the low-intensity fire portion of this regime caused sufficient uel buildup or changes in forest structure to cause significantly different results when a high-intensity crown fire burns through? Even in ponderosa pine and sequoia-mixed conifer forests, quantifying the changes caused by fire exclusion has just begun, and there is need for better information.

In the meantime, however, philosophical and policy questions have also been raised about the appropriateness of restoration efforts, and whether wilderness and park managers should (1) simply allow natural fires to burn; (2) reduce obvious fuel accumulations in certain zones with prescribed fires and then allow natural fires to burn; or (3) carefully restore natural structure to estimated presettlement conditions before allowing natural fires to burn (Bancroft and others 1985; Bonnicksen 1985; Kilgore 1985a; Lucas 1985; Worf 1985; Bonnicksen and Stone, in press; Parsons and others 1986). Graber (1983) has recently speculated on the proper role of National Park natural areas as ecosystem preserves. While allowing natural fires to burn has a broad philosophical appeal, it has drawbacks as well. In presettlement times, many lightning fires spread from areas outside present wilderness. In addition, some lightning fires currently ignited in wilderness will be suppressed. Hence, the more complex options need to be carefully evaluated.

How Important Were Aboriginals as Ignition Sources?

A recent review of the role of American Indians in the fire history of North American ecosystems makes clear that these peoples burned for many reasons, "including signaling, food gathering, hunting, forage and animal population management, vegetation management, maintenance of habitat diversity, and warfare" (Dennis and Wauer 1985). Such burning was done in different frequencies, intensities, locations, and seasons, and, as a result, the effects of such burning varied greatly from place to place (Gruell 1985; Lewis 1985; Arno 1985; Phillips 1985). It appears that Indian fires were of considerable significance in grassland, shrubland, and certain lower elevation forest types for at least a thousand years before European settlement (Arno 1985). Such fires, however, were not as common in upper elevation forests.

While some additional site-specific information gathered through research may be needed to understand how to simulate the role of Indian burning in a particular vegetation type or geographic area, we have considerable knowledge of this subject for most areas of North America and some parts of Australia. The more significant policy question is whether or not we want to restore Indian burning. During the 1983 Wilderness Fire Symposium, a workshop dealing with the role of Indian burning in wilderness concluded that development of additional philosophy and policy is needed to support future decision-making regarding whether wilderness managers should try to simulate Indian burning (Dennis and Wauer 1985). Because wilderness and park units are unique, with specific management needs, the workshop felt a blanket policy should not be adopted that would override site-specific characteristics and needs of individual areas.

Considerable concern has been expressed recently that simulating Indian burning would permanently implant our subjective judgment on when to ignite fires as well as freeze Indian culture at a point in time. Graber (1983) proposed instead that the National Park Service adopt "the unimpeded interaction of native ecosystem processes and structural elements" as the principal aim for park natural areas. Exceptions to this basic resource management goal would need to be explicitly stated and justified in plans for each area.

What Is "Natural" in Wilderness Fire Management?

While the term "natural" is often used in statements of goals or objectives for wilderness fire management programs, it does not yet have a common meaning in the literature of fire ecology or wilderness fire management. Researchers and managers of the earliest natural fire management program in the United States say that a prime need for their future programs is to define what is "natural" (Bancroft and others 1985).

The working definition developed for the 1983 Wilderness Fire Symposium, involving both the fire process and the resulting effects, was that:

> A natural fire for any given ecosystem (1) burns within the range (and frequency distribution) of fire intensities, frequencies, seasons, and sizes found in that ecosystem before arrival of western technological man, and (2) yields the range of fire effects results found in that ecosystem before the arrival of technological man (Kilgore 1985b).

There are four actions that may help clarify the meaning of "natural" in wilderness and park fire management programs:

1. Initiate quantitative research aimed at better defining changes in fuels and forest structure resulting from fire suppression during the past 50 to 100 years.
2. Initiate research to better characterize the fire regimes under which an ecosystem evolved. This should emphasize any role that high-intensity, stand-replacing fires may have played in presettlement times.
3. Using this information, develop an appropriate policy/philosophy decision process—involving value judgments rather than technical expertise or research—to decide (a) whether efforts will be made to restore community structure as it occurred at some given point in time, before fire will be allowed to interact with that structure to produce a "natural" ecosystem (Bonnicksen 1985), or (b) whether, instead, emphasis will be placed on the function of fire, not the structure of the ecosystem, and fire will be allowed to simply burn within the existing ecosystem structure or after fuels have been reduced. This assumes that structure would not be so different from conditions that have occurred at some point in the past as to be strongly detrimental to a "natural" outcome (Bancroft and others 1985; Parsons and others 1986).
4. Use the same decision process—and considerations raised by Graber (1983)—to decide whether or not Indian fires are to be considered "natural" and to be mimicked.

Large, High-Intensity, Stand-Replacing Fires in Wilderness

Two unresolved questions are: (1) Can we allow some of these crown fires to burn in certain wilderness units? and (2) should we do so? The first is a technical question subject to interpretation and conclusions using fire effects, behavior, and history data gathered by research. The second is a policy/philosophy question that makes use of such technical information, but relies heavily on value judgments for the answer. These fires occur in ecosystems involved with fire regimes 4, 5, and 6, where large, high-intensity, stand-replacing fires occurred at intervals ranging from 50 to 500 years or more. Managing wilderness fire programs involving such crown fires poses difficult fire control and human safety questions as well as complex ecological alternatives (Kilgore 1982; Heinselman 1985; Mutch and Davis 1985).

In his detailed review of this question at the 1983 Wilderness Fire Symposium, Heinselman (1985) lists five regions involved with such fire regimes:

1. The Great Lakes forest in Canada and the United States;
2. The New England and Acadian pine and certain spruce-fir forests;
3. The Canadian and Alaskan boreal forest;
4. The Rocky Mountain subalpine and upper montane zones from Alberta to Colorado and Utah; and
5. The Douglas-fir region of the Pacific Northwest.

In evaluating these fire regimes and regions, he notes that an important question is whether we can predict which stands will ignite readily and sustain crown fires if we know such things as stand age, species composition, and time since last fire. The answer depends on the local situation and on a better understanding of crown fire behavior than we now have, although some good work has been done (Van Wagner 1977, 1978; Albini 1979; Rothermel 1983). A similar question is whether we can predict potential maximum fire paths in a given area. One way that should not be ignored in developing management units in a natural fire management plan is to emphasize fire history, vegetation patterns, fuel loadings, aspect, and drainages where unusual fire behavior may be expected, because fires have a way of repeating themselves (Kilgore 1982; Heinselman 1985). Both the Ouzel Fire in Rocky Mountain National Park in Colorado in 1978 and the Mack Lake Fire in Michigan in 1980 tended to follow patterns of previous fires in the same area, but managers were apparently not aware of these patterns (Laven 1979; Simard 1981a).

In surveying fire experts concerning the meaning of "natural," I asked their impressions of how to handle high-intensity fires where these were found to be part of the presettlement fire history of a given ecosystem. A large majority philosophically favored letting such high-intensity fires burn, but nearly all added caveats to protect human life and property and avoid going beyond park and wilderness boundaries (Kilgore 1985b). Most felt an initial program of prescribed burning was desirable for fuel reduction. There was a sizable minority that felt either high-intensity crown fires are too hazardous to be acceptable, or that the areas in parks and wilderness are too small to accept this type of fire.

The questions of whether we can and should allow high-intensity fires to burn, therefore, remain to be answered. Only certain sizable areas, like Yellowstone National Park, WY, have allowed such fires to burn thus far. Perhaps there are a few other sizable wilderness and park units where this would be acceptable; small-sized units obviously must be ruled out. It would appear that instead of simply allowing such severe fires to burn, there is a greater willingness to consider using prescribed fire and perhaps "crowding" the prescription in a way that we might get results close to high-intensity, stand-replacing fires, but without the threats to human life encountered now by simply waiting for the inevitable wildfire. The alternative of total suppression has its drawbacks, as well, in that consequent fires will almost always burn under the worst possible fire control conditions, with high suppression costs and accompanying threats to human life and property.

DIRECTIONS FOR FUTURE RESEARCH

Needs for future research can be divided somewhat arbitrarily into technique needs and new information needs. Here is a brief listing of the higher priority wilderness fire research needs for the next decade.

Techniques/Methods Research

1. **Develop criteria by which managers can judge whether an ecosystem has been impacted in a major way by past fire suppression/exclusion.** Emphasis should be on ecosystems with intervals between fires considerably shorter than the duration of fire suppression efforts. Criteria must provide a way of judging changes in (a) fuels and (b) forest structure. They need to have a significance measure such as: Will the new level of fuels or patterns of forest structure lead to crown fires in ecosystems and fire regimes where they were not characteristic in presettlement time?

2. **Develop minimum impact methods for determining fire history in wilderness and park ecosystems.** This must include (a) interval between fires at a given site or stand; (b) fire intensity or severity; (c) size or areal extent of past fires; and (d) season of presettlement burning.

3. **Develop cost-effective techniques for restoring natural conditions over extensive areas of a wilderness or national park and demonstrate these methods.** Various combinations of manager-ignited prescribed burns and natural (lightning-caused) ignitions can be proposed and tested to determine the most efficient and effective ways of restoring both natural conditions and natural processes to ecosystems that have been impacted in major ways by man-caused fire exclusion.

4. **Develop standard techniques to help managers monitor performance of their wilderness fire plan.** Procedures for monitoring and evaluating natural fires and prescribed fires are needed for various forest ecosystems to enable researchers and managers to compare a planned fire regime to a "natural" fire regime in these ecosystems and to determine how well managers are implementing the plan and achieving their goal and objectives.

5. **Develop the capability to predict August behavior of natural fires ignited in July in wilderness areas.** These would probably be in the form of climatological probabilities to aid managers in decision making for long-duration lightning-caused fires.

6. **Develop special techniques for simulating the natural role of fire in wilderness areas where allowing natural (lightning-caused) fires to burn is impractical and where ignitions outside the wilderness no longer burn into the wilderness.** This will require using manager-ignited prescribed fires at frequencies, intensities, and seasons found in the presettlement period, to provide a close approximation of the natural fire history, behavior, and effects, but at the same time ensuring safety for human life and property. As an example, Pinnacles National Monument in California will use primarily prescribed (planned ignition) fire in legal wilderness (Agee and others 1980).

New Information Needs

1. **Using the best data available, determine what are the "natural" fire history, fire behavior, and fire effects for key short-return-interval wilderness ecosystems.** This will require using techniques developed above and an analysis of the existing range of fuel accumulations and forest structure patterns based on the expected range of fire frequency, intensity, size, and season. Judgments could then be made of how close to "natural" a given situation is.

2. **Document by case studies in key short-return-interval ecosystems how significantly current conditions depart from "natural" in terms of fuels and forest structure.** As an example, in a seral pine/larch/fir forest, knowing the mean and maximum intervals between fires in presettlement times, a researcher might check ages of young shade-tolerant species coming in under overstory canopy to determine what proportion exceed the historic maximum interval between fires. Current species composition of young shade-tolerant species might also be compared with similar composition in presettlement forests. Measurements would also be needed to check horizontal mosaic patterns, vertical forest structure (fuel laddering), and levels of ground, surface, and dead and living aerial fuels.

3. Through careful study and analysis of the results obtained from research priorities No. 1 and 2 above, **decide how precise we must be in restoring fuel levels and forest structure to key short-return-interval ecosystems before we allow natural forest to burn again.** In the sequoia-mixed conifer forests, for example, some researchers advocate fairly tight quantitative standards for restoration of vegetative aggregations found as part of a horizontal mosaic pattern in that ecosystem (Bonnicksen 1985), while some managers feel simply allowing natural fires (lightning-caused) to burn again in all ecosystems is best (Worf 1985). I tend to see a middle ground where prescribed fire could be used to reduce unnatural fuels and ameliorate major changes in forest structure (Kilgore 1985a), but without the precision suggested elsewhere (Bonnicksen and Stone 1982b). Managers are wrestling with these concepts and tend toward a conservative management strategy of "minimum intervention" (Bancroft and others 1985). These are difficult decisions, and research in the very near future could play an important role in clarifying the best way to achieve the common goal. That goal is to let "natural processes operate as freely as possible while minimizing the impacts of human actions—past and present—on wilderness ecosystems" (Kilgore 1985a).

4. In National Park and wilderness ecosystems where managers decide that Indian burning was part of the "natural" presettlement fire regime, **additional research may be needed on the relative importance of such aboriginal ignitions and lightning in determining intervals between fires and both intensities and severities of fire.** The difficult question of evolution of Indian culture will need careful consideration. Where appropriate, such information can then be utilized by managers in seeking to mimic the results of Indian burning through scheduled prescribed burns.

5. **Determine whether scheduled fairly high intensity prescribed burns can approximate the ecological effects of high-intensity, stand- replacing fires** (where these are part of the natural fire regime in wildernesses and National Parks) **under burning conditions less explosive than those characteristic of many such natural crown fires.** Only a few large wilderness units can ever hope to allow some of these high-intensity fires to burn. Few researchers have attempted to experiment with crown fire behavior and effects to date (Van Wagner 1977). Perhaps fire managers and researchers in the next decade can find ways to provide periodic stand renewal by prescribed burning without losing control of such fires (Alexander and Dubé 1983; Heinselman 1985).

6. **Determine fire effects relationships to habitat needs of endangered wilderness wildlife species such as the grizzly bear.** For example, fire is known to encourage growth of huckleberries (*Vaccinium* spp.), which are important seasonally in the diet of the grizzly. How much of the whitebark pine (*Pinus albicaulis*) type is seral and fire dependent, and what role does fire play in stimulating the pine nut crop, also apparently a staple food item for some grizzly populations (Kendall 1980)?

7. **Determine how suppression of fire has impacted key insect and disease populations in certain forest types through changes in age structure, species composition, and mosaic patterns of the forest.** Only through a better understanding of the natural interaction between forests, fires, key insects, and diseases can we understand how exclusion of fire may have made major ecosystem changes that encourage growth of insect and disease populations. Such ecosystem changes, in turn, may require that we modify the unnatural structural factors by subsequent prescribed fires to help restore a more natural ecosystem.

CONCLUSIONS

We know a great deal about fire in many ecosystems and fire regimes. Yet there is much more to learn. The next 10 years may well be the Decade of Wilderness Fire as Pyne (1985) contends. Most of the fire plans will be completed and the management decisions will be made. It, therefore, behooves us as researchers and resource managers to work closely together to seek to clarify our goals and objectives. While there are various interpretations of what Starker Leopold and his committee meant by some statements in the 1963 Leopold Report, the general philosophy is still clearly expressed in the admonition, "Above all other policies, the maintenance of naturalness should prevail!" While not easily or precisely defined, it is nevertheless imperative that the results of all our efforts take us as close to that ideal as possible—the ideal of allowing natural processes, including fire, to function unimpaired in National Park and wilderness ecosystems.

REFERENCES

Agee, J. K. Prescribed fire effects on physical and hydrologic properties of mixed-conifer forest floor and soil. Contribution Report No. 143. Davis, CA: Water Resources Center, University of California; 1973. 57 p.

Agee, J. K.; Clark, L. D.; Broyles, R. P.; Rose, L. Wilderness fire management at Pinnacles National Monument. Fire Management Notes. 42(1): 10-12; 1980.

Agee, J. K.; Dunwiddie, P. W. Recent forest development on Yellow Island, San Juan County, Washington. Canadian Journal of Forest Research. 62(10): 2074-2080; 1984.

Agee, J. K.; Flewelling, R. A fire cycle model based on climate for the Olympic Mountains, Washington. In: Seventh conference on forest and fire meteorology: proceedings. Fort Collins, CO: American Meteorological Society; 1983: 32-37.

Agee, James K.; Smith, L. Subalpine tree reestablishment after fire in the Olympic Mountains, Washington. Ecology. 65(3): 810-819; 1984.

Agee, J. K.; Wakimoto, R. H.; Biswell, H. H. Fire and fuel dynamics of Sierra Nevada conifers. Forest Ecology and Management. 1: 255-265; 1978.

Ahlgren, I. F.; Ahlgren, C. E. Ecological effects of forest fires. Botany Review. 26: 483-533; 1960.

Albini, Frank A. Estimating wildfire behavior and effects. General Technical Report INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 92 p.

Albini, F. A. Spot fire distance from burning trees—a predictive model. General Technical Report INT-56. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 73 p.

Aldrich, D. F.; Mutch, R. W. Wilderness fire management guidelines and inventory procedures. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1973. 36 p. Unpublished.

Alexander, M. E. Reconstructing the fire history of Pukaskwa National Park. In: Fire ecology in resources management: Proceedings of a workshop; 1977 December 6-7; Edmonton, AB. Information Report NOR-X-210. Edmonton, AB: Environment Canada, Canadian Forestry Service, Northern Forest Research Centre; 1978: 4-11.

Alexander, M. E. Bibliography and a résumé of current studies on fire history. Report O-X-304. Sault Ste. Marie, ON: Environment Canada, Canadian Forestry Service, Great Lakes Forest Research Centre; 1979. 43 p.

Alexander, Martin E. Forest fire history research in Ontario: a problem analysis. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO:

U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 96-109.

Alexander, M. E.; Dubé, D. E. Fire-management in wilderness areas, parks, and other nature reserves. In: Wein, R. W.; MacLean, D. A., eds. The role of fire in northern circumpolar ecosystems. SCOPE 18 Series. New York: John Wiley & Sons; 1983: 273-297.

Alexander, Martin E.; Hawksworth, F. G. Fire and dwarf mistletoes in North American coniferous forest. Journal of Forestry. 74(7): 446-449; 1976.

Anderson, Hal E. Sundance Fire: an analysis of fire phenomena. Research Paper INT-56. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1968. 39 p.

Andrews, P. L. BEHAVE: fire behavior prediction and fuel modeling system—BURN subsystem, part I. General Technical Report INT-194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 130 p.

Antos, Joseph Avery. Grand fir (*Abies grandis* [Dougl.] Forbes) forests of the Swan Valley, Montana. Missoula, MT: University of Montana; 1977. 220 p. M.A. thesis.

Arno, S. F. The historical role of fire on the Bitterroot National Forest. Research Paper INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 29 p.

Arno, S. F. Forest fire history in the northern Rockies. Journal of Forestry. 78(8): 460-465; 1980.

Arno, Stephen F. Ecological effects and management implications of Indian fires. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 81-86.

Arno, S. F.; Davis, D. H. Fire history of western redcedar/hemlock forests in northern Idaho. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 21-26.

Arno, S. F.; Sneck (Davis), K. M. A method for determining fire history in coniferous forests of the Mountain West. General Technical Report INT-42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 28 p.

Arno, S. F.; Petersen, T. D. Variation in estimates of fire intervals: a closer look at fire history on the Bitterroot National Forest. Research Paper INT-301. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 8 p.

Baker, J. O., Jr. A selected and annotated bibliography for wilderness fire managers. Washington, DC: U.S. Department of Agriculture; 1975. 36 p.

Bancroft, W. L.; Partin, W. A. Fire management plan, Sequoia and Kings Canyon National Parks. Three Rivers, CA: U.S. Department of the Interior, National Park Service; 1979. 190 p.

Bancroft, Larry; Nichols, Thomas; Parsons, David; Graber, David; Evison, Boyd; van Wagtendonk, Jan. Evolution of the natural fire management program at Sequoia and Kings Canyon National Parks. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 174-180.

Barrett, S. W. Indian fires in the presettlement forests of western Montana. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 35-41.

Barrett, S. W. Relationship of Indian-caused fires to the ecology of western Montana forests. Missoula, MT: University of Montana; 1981. 198 p. M.S. thesis.

Barrett, S. W. Fire effects on insects/diseases: bibliographic data base. Final Report, Cooperative Agreement 22-C-3-INT-30. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Fire Sciences Laboratory; 1985. 30 p.

Beaufait, W. R.; Hardy, C. E.; Fischer, W. C. Broadcast burning in larch-fir clearcuts - the Miller Creek-Newman Ridge study. Research Paper INT-175. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 54 p.

Behan, M. J. The cycle of minerals in forest ecosystems. In: Role of fire in the Intermountain West: Proceedings of a symposium; 1970 October 27-29; Missoula, MT. Missoula, MT: Intermountain Fire Research Council; 1970: 11-29.

Bendell, J. F. Effects of fire on birds and mammals. In: Fire and ecosystems. New York: Academic Press; 1974: 73-138.

Biswell, H. H. The use of fire in wildland management in California. In: Natural resources: quality and quantity. Berkeley, CA: University of California Press; 1967: 71-87.

Biswell, H. H.; Gibbens, R. P.; Buchanan, H. Litter production by bigtrees and associated species. California Agriculture. 20(9): 5-7; 1966.

Biswell, H. H.; Gibbens, R. P.; Buchanan, H. Fuel conditions and fire hazard reduction costs in giant sequoia forests. California Agriculture. 22: 2-4; 1968.

Bock, J. H. Introductory remarks: communication between ecologists and managers. In: Proceedings, Tall Timbers fire ecology conference No. 14 and Intermountain Fire Research Council fire and land management symposium; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station; 1976: 193.

Boerner, Ralph E. J. Fire and nutrient cycling in temperate ecosystems. Bioscience. 32(3): 187-192; 1982.

Bonnicksen, Thomas M. Ecological information base for park and wilderness fire management planning. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 168-173.

Bonnicksen, Thomas M.; Stone, E. C. The giant sequoia-mixed conifer forest community characterized through pattern analysis as a mosaic of aggregations. Forest Ecology and Management. 3(4): 307-328; 1981.

Bonnicksen, T. M.; Stone, E. C. Managing vegetation within U.S. National Parks: a policy analysis. Environmental Management. 6(2): 109-122; 1982a.

Bonnicksen, T. M.; Stone, E. C. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology. 64(3): 1134-1148; 1982b.

Bonnicksen, Thomas M.; Stone, Edward C. Restoring naturalness to National Parks. Environmental Management. [In press].

Books, David J.; Heinselman, Miron L.; Ohmann, Lewis F. Revegetation research on the Little Sioux Burn. Naturalist. 22(4): 12-21; 1971.

Botkin, Daniel B.; Sobel, J. J. Stability in time-varying ecosystems. American Naturalist. 109(907): 625-646; 1975.

Botti, S. J. Natural, conditional, and prescribed fire management plan. Yosemite National Park, CA: U.S. Department of the Interior, National Park Service; 1979. 50 p.

Bradshaw, Larry S.; Fischer, William C. A computer system for scheduling fire use. Part I: the system. General Technical Report INT-91. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 63 p.

Britton, C. M.; Clark, R. G. Evaluating prescribed burns. Presented at a U.S. Fish and Wildlife prescribed fire workshop at the Malheur Wildlife Refuge; 1981 November. Unpublished.

Brown, J. K. Fire cycles and community dynamics in lodgepole pine forest. In: Baumgartner, D. J., ed. Management of lodgepole pine ecosystems: Proceedings of the symposium. Pullman, WA: Washington State University, Cooperative Extension Service; 1975: 429-456.

Brown, James K. The "unnatural fuel buildup" issue. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 127-128.

Brown, James K.; DeByle, Norbert V. Developing prescribed burning prescriptions for aspen in the Intermountain West. In: Lotan, James E., ed. Fire—its field effects: Proceedings of the symposium; 1982 October 19-21; Jackson, WY. Missoula, MT: Intermountain Fire Council; Pierre, SD: Rocky Mountain Fire Council; 1982: 29-49.

Brown, James K.; Oberheu, Rick D.; Johnston, Cameron M. Handbook for inventorying surface fuels and biomass in the Interior West. General Technical Report INT-129. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 48 p.

Burgan, Robert E. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculator: user's manual. General Technical Report INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 25 p.

Burgan, Robert E.; Rothermel, Richard C. Fire behavior prediction and fuel modeling system - FUEL subsystem. General Technical Report INT-167. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 126 p.

Byrne, Roger; Michaelsen, Joel; Soutar, Andrew. Fossil charcoal as a measure of wildlife frequency in southern California: a preliminary analysis. In: Mooney, H. A.; Conrad, C. E., eds. Environmental consequences of fire and fuel management in Mediterranean ecosystems. General Technical Report WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 361-367.

Carlson, Clinton E.; Schmidt, Wyman C.; Fellin, David G. The role of fire in western spruce budworm dynamics: is wilderness a factor? In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 318-322.

Chandler, C.; Cheney, P.; Thomas, P.; Trabaud, L.; Williams, D. Fire in forestry. Vol. 1. New York: John Wiley & Sons; 1983. 450 p.

Chapman, H. H. Forest fires and forestry in the southern states. American Forests. 18: 510-517; 1912.

Clements, F. E. The life history of lodgepole burn forests. Bulletin 79. Washington, DC: U.S. Department of Agriculture; 1910. 56 p.

Conrad, C. Eugene; Oechel, Walter, tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. General Technical Report PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982. 637 p.

Cooper, C. F. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs. 30: 129-164; 1960.

Cooper, Charles F. Pattern in ponderosa pine forest. Ecology. 42: 493-499; 1961.

Craighead, F. C. The trees of south Florida. Coral Gables, FL: University of Miami Press; 1971. 212 p.

Craighead, F. C. Hammocks in south Florida. In: Gleason, P. J., ed. Environments of south Florida: present and past. Miami, FL: Miami Geological Society; 1974: 53-60.

Craighead, John J.; Sumner, J. S.; Scaggs, G. B. A definitive system for analysis of grizzly bear habitat and other wilderness resources: utilizing LANDSAT multispectral imagery and computer technology. Monograph No. 1. Missoula, MT: Wildlife-Wildlands Institute; University of Montana Foundation; 1982: 270-277.

Cwynar, Les C. The recent fire history of Barron Township, Algonquin Park. Canadian Journal of Botany. 55: 1524-1538; 1977.

Davis, K. M. Fire history of a western larch/Douglas-fir forest type in northwestern Montana. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 69-74.

Davis, K. M.; Clayton, B. D.; Fischer, W. C. Fire ecology of Lolo National Forest habitat types. General Technical Report INT-79. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 77 p.

Deeming, J. E.; Burgan, R. E.; Cohen, J. D. The National Fire-Danger Rating System - 1978. General Technical Report INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 63 p.

Dennis, John; Wauer, Roland. Role of Indian burning in wilderness fire planning. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 296-298.

Despain, D. G. Some effect of free-burning fires in Yellowstone National Park. In: Lotan, James E., ed. Fire—its field effects: Proceedings of the symposium; 1982 October 19-21; Jackson, WY. Missoula, MT: Intermountain Fire Council; Pierre, SD: Rocky Mountain Fire Council; 1982: 93-101.

Despain, D. G. Nonpyrogenous climax lodgepole pine communities in Yellowstone National Park. Ecology. 64(2): 231-234; 1983.

Despain, D. G.; Sellers, R. E. Natural fire in Yellowstone National Park. Western Wildlands. 4(1): 20-24; 1977.

Dieterich, J. H. Chimney Spring forest fire history. Research Paper RM-220. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980a. 8 p.

Dieterich, J. H. The composite fire interval - a tool for more accurate interpretation of fire history. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980b: 8-14.

Dieterich, J. H. Fire history of southwestern mixed conifer: a case study. Forest Ecology and Management. 6: 13-31; 1983.

Dieterich, John H.; Swetnam, Thomas W. Dendrochronology of a fire-scarred ponderosa pine. Forest Science. 30(1): 238-247; 1984.

Fahnestock, G. R. Two keys for appraising forest fire fuels. Research Paper PNW-99. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1970. 26 p.

Fahnestock, G. R. Fires, fuels, and flora as factors in wilderness management: the Pasayten case. In: Proceedings, Tall Timbers fire ecology conference No. 15; 1974 October 16-17; Portland, OR. Tallahassee, FL: Tall Timbers Research Station; 1976: 33-69.

Fahnestock, George R. Interactions of forest fire, flora, and fuels in two Cascade Range wilderness areas. Seattle, WA: University of Washington; 1977. Dissertation. [Diss. Abstr. Int. 38: 2451-B.]

Fahnestock, George R.; Agee, James K. Biomass consumption and smoke production by prehistoric and modern forest fires in western Washington. Journal of Forestry. 81(10): 653-657; 1983.

Ferry, Gardner; Abeita, Fernando; Bancroft, Larry; [and others]. Prescribed fire smoke management guide 420-1. Washington, DC: National Wildfire Coordinating Group, Prescribed Fire and Fire Effects Working Team; 1985. 28 p.

Fischer, W. C.; Hardy, C. E. Fire-weather observer's handbook. Agriculture Handbook 494. Washington, DC: U.S. Department of Agriculture, Forest Service; 1976. 142 p.

Franklin, J. F. Wilderness ecosystems. In: Hendee, J. D.; Stankey, G. H.; Lucas, R. C. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 191-212.

Franklin, Jerry F.; Dyrness, C. T. Natural vegetation of Oregon and Washington. General Technical Report PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.

Franklin, J. F.; Hemstrom, M. A. Aspects of succession in the coniferous forests of the Pacific Northwest. In: West, D. C.; Shugart, H. H.; Botkin, D. B., eds. Forest succession, concepts and application. New York: Springer-Verlag; 1981: 212-229.

Frissell, S. S., Jr. The importance of fire as a natural ecological factor in Itasca State Park, Minnesota. Quaternary Research. 3(3): 397-407; 1973.

Fritz, Emanuel. The role of fire in the redwood region. Circular 323. Berkeley, CA: University of California; 1932. 23 p.

Froelich, R. C.; Hodges, C. S., Jr.; Sackett, S. S. Prescribed burning reduces severity of *Annosus* root rot in the South. Forest Science. 24(1): 93-100; 1978.

Gabriel, H. W. Wilderness ecology: the Danaher Creek drainage, Bob Marshall Wilderness, Montana. Missoula, MT: University of Montana; 1976. 224 p. Dissertation.

Gara, R. J.; Littke, W. R.; Agee, J. K.; Geiszler, D. R.; Stuart, J. D.; Driver, C. H. Influence of fires, fungi, and mountain pine beetles on development of a lodgepole pine forest in south-central Oregon. In:

Baumgartner, David M.; Krebill, Richard G.; Arnott, James T.; Weetman, Gordon F., eds. Lodgepole pine: the species and its management: Symposium proceedings; 1984 May 8-10; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University; 1985: 153-162.

Giles, R. H. Wildlife management techniques. Washington, DC: The Wildlife Society; 1969. 623 p.

Gill, A. Malcolm. Effects of fire on Australia's native vegetation. Annual Report. Canberra, Australia: CSIRO Division of Forest Research; 1973.

Gill, A. M.; Groves, R. H.; Noble, I. R., eds. Fire and the Australian biota; Australian National Committee of SCOPE; 1978 October 9-11; [location unknown]. Canberra, Australia: Australian Academy of Science; 1981. 582 p.

Gleason, C. H. Reconnaissance methods of measuring erosion. Journal of Soil and Water Conservation. 12(3): 105-107; 1957.

Good, R. B. The role of fire in conservation reserves. In: Gill, A. M.; Groves, R. H.; Noble, I. R., eds. Fire and the Australian biota; Australian National Committee of SCOPE; 1978 October 9-11; [location unknown]. Canberra, Australia: Australian Academy of Science; 1981: 529-549.

Graber, D. M. Rationalizing management of natural areas in National Parks. The George Wright Forum. 3(4): 48-56; 1983.

Greene, S. W. The forest that fire made. American Forests. 37(10): 583-584, 618; 1931.

Gruell, G. E. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Vol. 1—photographic record analysis. Research Paper INT-235. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 207 p.

Gruell, G. E. Fire and vegetative trends in the Northern Rockies: interpretations from 1871-1982 photographs. General Technical Report INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 117 p.

Gruell, George E. Indian fires in the interior West: a widespread influence. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 68-74.

Gruell, G. E.; Loope, L. L. Relationships among aspen, fire, and ungulate browsing in Jackson Hole, Wyoming. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1974. 33 p.

Habeck, J. R. Fire ecology investigations in Selway-Bitterroot Wilderness: historical considerations and current observations. Publication No. R1-72-001. Missoula, MT: University of Montana and U.S. Department of Agriculture, Forest Service, Northern Region; 1972. 118 p.

Habeck, J. R. Forests, fuels and fire in the Selway-Bitterroot Wilderness, Idaho. In: Proceedings, Tall Timbers fire ecology conference No. 14 and Intermountain Fire Research Council fire and land management symposium; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station; 1976: 305-353.

Habeck, James R. Impact of fire suppression on forest succession and fuel accumulations in long-fire-interval wilderness habitat types. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 110-118.

Habeck, J. R.; Mutch, R. W. Fire-dependent forests in the Northern Rocky Mountains. Quaternary Research. 3: 408-424; 1973.

Hall, F. C. Fire and vegetation in the Blue Mountains - implications for land managers. In: Proceedings, Tall Timber fire ecology conference No. 15; 1974 October 16-17; Portland, OR. Tallahassee, FL: Tall Timbers Research Station; 1976: 155-169.

Hare, R. C. Heat effects on living plants. Occasional Paper 183. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1961. 32 p.

Harper, R. M. A defense of forest fires. Literary Digest. 47: 208; 1913.

Hartesveldt, Richard J. Fire ecology of the giant sequoias: controlled fire may be one solution to survival of the species. Natural History Magazine. 73(10): 12-19; 1964.

Hartesveldt, R. J.; Harvey, H. T. The fire ecology of sequoia regeneration. In: Proceedings, Tall Timbers fire ecology conference No. 7; 1967 November 9-10; Lake County, CA. Tallahassee, FL: Tall Timbers Research Station; 1967: 65-77.

Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. Giant sequoia ecology: fire and reproduction. Scientific Monograph Series No. 12. Washington, DC: U.S. Department of the Interior, National Park Service; 1980. 182 p.

Hawkes, B. C. Fire history of Kananaskis Provincial Park - mean fire return intervals. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 42-45.

Heinselman, M. L. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research. 3(3): 329-382; 1973.

Heinselman, M. L. Fire in wilderness ecosystems. In: Hendee, J. C.; Stankey, G. H.; Lucas, R. C., eds. Wilderness management. Miscellaneous Publication No. 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 249-278.

Heinselman, M. L. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. In: Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., eds.

Fire regimes and ecosystems properties. General Technical Report WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 7-57.

Heinselman, Miron L. Fire regimes and management options in ecosystems with large high-intensity fires. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 101-109.

Hemphill, Martha Lynn. Fire, vegetation, and people—charcoal and pollen analyses of Sheep Mountain Bog, Montana: the last 2,800 years. Pullman, WA: Washington State University; 1983. 70 p. M.S. thesis.

Hemstrom, M. A.; Franklin, J. F. Fire and other disturbances of the forests in Mount Rainier National Park. Quaternary Research. 18: 32-51; 1982.

Hendrickson, W. H. Perspective on fire and ecosystems in the United States. In: Fire in the environment symposium; 1972 May 1-5; Denver, CO. Washington, DC: U.S. Department of Agriculture, Forest Service; 1972: 29-33.

Heyward, F.; Barnette, R. M. Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Technical Bulletin 265. Gainesville, FL: Florida Agricultural Experiment Station; 1934. 39 p.

Hodgson, A. Fire management in eucalypt forests. In: Proceedings, Tall Timbers fire ecology conference No. 6; 1967 March 6-7; Tallahassee, FL. Tallahassee, FL: Tall Timbers Research Station; 1967: 97-111.

Hofsteter, R.; Parsons, F. Effects of fire in the ecosystem: an ecological study of the effects of fire on the wet prairie, sawgrass glades, and pineland communities of south Florida. Final Report Part 2. EVER-N-48, NTIS No. PB-264463. Washington, DC: U.S. Department of the Interior, National Park Service; 1975. Mimeo report.

Holling, C. S. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics. 4: 1-23; 1973.

Houston, D. B. Wildfire in northern Yellowstone National Park. Ecology. 54(5): 1111-1117; 1973.

Houston, D. B. The northern Yellowstone elk—ecology and management. New York: Macmillan; 1982. 474 p.

Huff, M. H. Post-fire succession in the Olympic Mountains, Washington: forest vegetation, fuels, and avifauna. Seattle, WA: University of Washington; 1984. 240 p. Dissertation.

Huntley, B. J. South African programme for the SCOPE mid-term project on the ecological effects of fire. South African National Scientific Programmes Report No. 32. Pretoria, South Africa: Council for Scientific and Industrial Research; 1978. 36 p.

Jacobs, Diana F.; Cole, Dana W.; McBride, Joe R. Fire history and perpetuation of natural coast redwood ecosystems. [In press].

Keeley, Jon E. Reproductive cycles and fire regimes. In: Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., eds. Fire regimes and ecosystem properties. General Technical Report WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 231-277.

Keeley, Jon E.; Zedler, Paul H. Reproduction of chaparral shrubs after fire: a comparison of sprouting and seeding strategies. American Midland Naturalist. 99(1): 142-161; 1978.

Keen, F. P. Longevity of ponderosa pine. Journal of Forestry. 38: 597-598; 1940.

Kendall, Katherine C. Use of pine nuts by grizzly and black bears in the Yellowstone area. International Conference on Bear Research and Management. 5: 166-173; 1980.

Kendeigh, S. C. Measurement of bird populations. Ecological Monographs. 14: 67-106; 1944.

Keown, Larry D. Fire management in the Selway-Bitterroot Wilderness. Grangeville, ID: U.S. Department of Agriculture, Forest Service, Nezperce National Forest, Moose Creek Ranger District; 1980. 67 p.

Keown, Larry D. Case study: the Independence Fire, Selway-Bitterroot Wilderness. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985a: 239-247.

Keown, Larry D. Fire behavior prediction techniques for park and wilderness fire planning. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985b: 162-167.

Kercher, J. R.; Axelrod, M. C. A process model of fire ecology and succession in a mixed-conifer forest. Ecology. 65: 1725-1742; 1984.

Kilgore, B. M. Response of breeding bird populations to habitat changes in a giant sequoia forest. American Midland Naturalist. 85(1): 135-152; 1971a.

Kilgore, B. M. The role of fire in managing red fir forests. In: Transactions of the 36th North American wildlife and natural resources conference; 1971 March 7-10; Portland, OR. Washington, DC: Wildlife Management Institute; 1971b: 405-416.

Kilgore, B. M. Fire's role in a sequoia forest. Naturalist. 23(1): 26-37; 1972.

Kilgore, B. M. Impact of prescribed burning on a sequoia-mixed conifer forest. In: Proceedings, Tall Timbers fire ecology conference No. 12; 1972 June 8-9; Lubbock, TX. Tallahassee, FL: Tall Timbers Research Station; 1973a: 345-375.

Kilgore, B. M. The ecological role of fire in Sierran conifer forests: its application to national park management. Quaternary Research. 3(3): 496-513; 1973b.

Kilgore, B. M. From fire control to fire management: an ecological basis for policies. In: Transactions of the 41st North American wildlife and natural resources conference; 1976 March 22-24; Washington, DC. Washington, DC: Wildlife Management Institute; 1976: 477-493.

Kilgore, B. M. Fire in ecosystem distribution and structure: western forest and shrublands. In: Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., eds. Fire regimes and ecosystem properties. General Technical Report WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 58-89.

Kilgore, B. M. Fire management programs in parks and wilderness. In: Lotan, James E.; ed. Fire—its field effects: Proceedings of the symposium; 1982 October 19-21; Jackson, WY. Missoula, MT: The Intermountain Fire Council; Pierre, SD: The Rocky Mountain Fire Council; 1982: 61-91.

Kilgore, Bruce M. Panel on fire management in research natural areas: summary comments. In: Johnson, Janet L.; Franklin, Jerry F.; Krebill, Richard G., coords. Research natural areas: baseline monitoring and management: Proceedings of a symposium; 1984 March 21; Missoula, MT. General Technical Report INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984: 66-67.

Kilgore, Bruce M. Human-ignited prescribed fires in wilderness: a response to Bill Worf. In: Proceedings, symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985a: 283-285.

Kilgore, Bruce M. What is "natural" in wilderness fire management? In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985b: 57-67.

Kilgore, Bruce M.; Biswell, H. H. Seedling germination following fire in a giant sequoia forest. California Agriculture. 25(2): 8-10; 1971.

Kilgore, B. M.; Briggs, G. S. Restoring fire to high elevation forests in California. Journal of Forestry. 70(5): 266-271; 1972.

Kilgore, B. M.; Sando, R. W. Crown-fire potential in a sequoia forest after prescribed burning. Forest Science. 21(1): 83-87; 1975.

Kilgore, B. M.; Taylor, D. Fire history of a sequoia-mixed conifer forest. Ecology. 60: 129-142; 1979.

Koehler, Gary M.; Hornocker, Maurice G. Fire effects on marten habitat in the Selway-Bitterroot Wilderness. Journal of Wildlife Management. 41(3): 500-505; 1977.

Komarek, E. V. Fire and animal behavior. In: Proceedings, Tall Timbers fire ecology conference No. 9; 1969 April 10-11; Tallahassee, FL. Tallahassee, FL: Tall Timbers Research Station; 1969: 161-207.

Komarek, E. V., Sr. Comments on the history of controlled burning in the southern United States, In: Proceedings, 17th annual watershed symposium; 1973 September 19; Phoenix, AZ. Phoenix, AZ: Arizona Water Resources Committee; 1973: 11-17.

Kozlowski, T. T.; Ahlgren, C. E., eds. Fire and ecosystems. New York: Academic Press; 1974. 542 p.

Kramp, Betty A.; Patton, David R.; Brady, Ward W. The effects of fire on wildlife habitat and species. RUN WILD Wildlife/Habitat Relationships Technical Report. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region; 1983. 29 p.

Laven, R. D. Natural fire management in Rocky Mountain National Park: a case study of the Ouzel Fire. In: Proceedings, second conference on scientific research in the national parks. Washington, DC: U.S. Department of the Interior, National Park Service; 10: 37-45; 1979.

Leopold, Aldo. Wilderness and its place in forest recreational policy. Journal of Forestry. 19(7): 718-721; 1921.

Leopold, Aldo. A Sand County almanac and sketches here and there. New York: Oxford University Press; 1949. 226 p.

Leopold, A. S.; Cain, S. A.; Cottam, C. M.; Gabrielson, I. N.; Kimball, T. L. Study of wildlife problems in national parks: wildlife management in national parks. Transactions, North American wildlife and natural resources conference. 28: 28-45; 1963.

Lewis, H. T. Makuta: the ecology of Indian fires in northern Alberta. Western Canada Journal of Anthropology. 11(15): 15-52; 1977.

Lewis, H. T. Hunter-gatherers and problems for fire history. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 115-119.

Lewis, Henry T. Why Indians burned: specific versus general reasons. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 75-80.

Lockwood, Douglas. I, the Aboriginal. London: Cassell and Co., Ltd.: 1962. 240 p.

Loope, Lloyd L. Dynamics of forest communities in Grand Teton National Park. Naturalist. 22(1): 39-47; 1971.

Loope, L. L.; Gruell, G. E. The ecological role of fire in the Jackson Hole area, northwestern Wyoming. Quaternary Research. 3(3): 425-443; 1973.

Lotan, J. E.; Alexander, M. E.; Arno, S. F.; [and others]. Effects of fire on flora: a state-of-the-knowledge review. General Technical Report WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981. 71 p.

Lotan, James E.; Brown, James K.; Neuenschwander, Leon F. Role of fire in lodgepole pine forests. In: Baumgartner, David M.; Krebill, Richard G.; Arnott, James T.; Weetman, Gordon F., eds. Lodgepole pine: the species and its management: Symposium proceedings; 1984 May 8-10; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University; 1985: 133-152.

Loucks, Orie L. Evolution of diversity, efficiency, and community stability. American Zoology. 10: 17-25; 1970.

Lopoukhine, Nikita. Guiding philosophy for management of fire and vegetation in Canadian Parks. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 16-20.

Lucas, Robert C. Planned ignitions in wilderness: response to paper by William A. Worf. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 286-290.

Lunan, J. S.; Habeck, J. R. The effects of fire exclusion on ponderosa pine communities in Glacier National Park. Canadian Journal of Forest Research. 3: 574-579; 1973.

Lyon, L. Jack. Vegetal development on the Sleeping Child Burn in western Montana, 1961-1973. Research Paper INT-184. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 24 p.

Lyon, L. Jack. The Sleeping Child Burn—21 years of postfire change. Research Paper INT-330. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 17 p.

Lyon, L. J.; Crawford, H. S.; Czuhai, E.; [and others]. Effects of fire on fauna: a state-of-the-knowledge review. General Technical Report WO-6. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 41 p.

Madany, Michael H.; Swetnam, Thomas W.; West, Neil E. Comparison of two approaches for determining fire dates from tree scars. Forest Science. 28(4): 856-861; 1982.

Madel, Michael J. Grizzly bear habitat delineation and reconnaissance in the Cabinet Mountains: a procedural description. In: Cumulative effects analysis process. Libby, MT: U.S. Department of Agriculture, Forest Service, Kootenai National Forest; 1982. 38 p. Mimeo.

Maissurow, D. K. Fire as a necessary factor in the perpetuation of white pine. Journal of Forestry. 33(4): 373-378; 1935.

Martin, Robert E.; Robinson, D. D.; Schaeffer, W. E. Fire in the Pacific Northwest—perspectives and problems. In: Proceedings, Tall Timbers fire ecology conference No. 15; 1974 October 16-17; Portland, OR. Tallahassee, FL: Tall Timbers Research Station; 1976: 1-23.

Mastrogiuseppe, M. E.; Alexander, M. E.; Romme, W. H. Forest and rangeland bibliography. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; Northern Forest Fire Laboratory; 1983. 49 p.

May, R. M. Stability and complexity in model ecosystems. Princeton, NJ: Princeton University Press; 1973. 235 p.

McBride, Joe R. Analysis of tree rings and fire scars to establish fire history. Tree-Ring Bulletin. 43: 51-67; 1983.

McBride, Joe R; Laven, Richard D. Scars as an indicator of fire frequency in the San Bernardino Mountains, California. Journal of Forestry. 74: 439-442; 1976.

McNeil, R. C.; Zobel, D. B. Vegetational fire history of a ponderosa pine-white fir forest in Crater Lake National Park. Northwest Science. 54(1): 30-46; 1980.

Means, Joseph E. Determining the age of a single bole scar by increment coring. Bulletin of the Ecological Society of America. 66(2): 230; 1985. Abstract.

Mehringer, P. J., Jr.; Arno, S. F.; Petersen, K. L. Postglacial history of Lost Trail Pass Bog, Bitterroot Mountains, Montana. Arctic and Alpine Research. 9(4): 345-368; 1977.

Methven, Ian R. Fire research at the Petawawa Forest Experiment Station: the integration of fire behavior and forest ecology for management purposes. In: Dubè, D. E., ed. Fire ecology in resource management workshop proceedings; 1977 December 6-7; [location unknown]. Information Report NOR-X-210. Edmonton, AB: Northern Forest Research Centre, Canadian Forestry Service; 1978: 23-27.

Miller, J. M.; Keen, F. P. Biology and control of the western pine beetle: a summary of the first fifty years of research. Miscellaneous Publication 800. Washington, DC: U.S. Department of Agriculture, Forest Service; 1960. 381 p.

Mobley, H. E.; Arden, C. R.; Crown, A. B.; Fender, D. E.; Jay, D. M.; Winkworth, R. C. Southern forestry smoke management guidebook. General Technical Report SE-110. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1976. 140 p.

Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., eds. Fire regimes and ecosystem properties: proceedings of the conference; 1978 December 11-15; Honolulu, HI. General Technical Report WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981. 594 p.

Mooney, Harold A.; Conrad, C. Eugene, eds. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. General Technical Report WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977. 498 p.

Muraro, S. J. The lodgepole pine fuel complex. Information Report BC-X-53. Victoria, BC: Department of Fish and Forestry, Canadian Forestry Service, Forestry Research Laboratory; 1971. 35 p.

Mutch, R. W. Wildland fires and ecosystems—a hypothesis. Ecology. 51(6): 1046-1051; 1970.

Mutch, Robert W. "I thought forest fires were black!" Western Wildlands. 1(3): 16-22; 1974.

Mutch, Robert W.; Davis, Kathleen M. Visitor protection in parks and wildernesses: preventing fire-related accidents and disasters. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 149-158.

Norum, R. A.; Fischer, W. C. Determining the moisture content of some dead forest fuels using a microwave oven. Research Note INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 7 p.

Nudds, T. D. Quantifying the vegetative structure of wildlife cover. Wildland Society Bulletin. 5: 113-117; 1977.

Orians, G. H. Diversity, stability, and maturity in natural ecosystems. In: van Dobben, W. H.; Lowe-McConnell, R. H., eds. Unifying concepts in ecology. The Hague: Junk; 1975: 64-65.

Parker, Albert J. Persistence of lodgepole pine forests in the central Sierra Nevada. Ecology. [In press.]

Parker, M. L. Techniques in X-ray densitometry of tree-ring samples. Paper presented at 45th annual meeting of Northwest Scientific Association; 1972 March 24; Bellingham, WA. Bellingham, WA: Western Washington State College; 1972.

Parmeter, John R., Jr. Effects of fire on pathogens. In: Mooney, Harold A.; Conrad, C. Eugene, eds. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. General Technical Report WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977: 58-64.

Parmeter, J. R., Jr. Forest stand dynamics and ecological factors in relation to dwarf mistletoe spread, impact, and control. In: Scharpf, R. F.; Parmeter, J. R., tech. coords. Dwarf mistletoe control through forest management: Proceedings of the symposium; 1978 April 11-13; Berkeley, CA. General Technical Report PSW-31. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1978: 16-30.

Parsons, D. J. Fire and fuel accumulation in a giant sequoia forest. Journal of Forestry. 76(2): 104-105; 1978.

Parsons, D. J. The role of fire management in maintaining natural ecosystems. In: Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., eds. Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. General Technical Report WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 469-488.

Parsons, D. J.; DeBenedetti, S. H. Impact of fire suppression on mixed-conifer forest. Forest Ecology and Management. 2: 21-33; 1979.

Parsons, D. J.; Graber, D. M.; Agee, J. K.; van Wagtendonk, J. W. Natural fire management in national parks. Environmental Management. 10(1): 21-24; 1986.

Phillips, Clinton B. The relevance of past Indian fires to current fire management programs. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 87-92.

Phillips, J. Effects of fire in forest and savanna ecosystems of sub-Saharan Africa. In: Fire and ecosystems. New York: Academic Press; 1974: 435-481.

Philpot, Charles W. Vegetative features as determinants of fire frequency and intensity. In: Mooney, Harold A.; Conrad, C. Eugene, eds. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. General Technical Report WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977: 12-16.

Pickford, Stewart G.; Fahnestock, George R.; Ottmar, Roger. Fuels, weather, and lightning fires in the Olympic National Park. Contract No. CX-9000-6-0116. Washington, DC: U.S. Department of the Interior, National Park Service; Seattle, WA: College of Forest Resources, University of Washington; 1977. 92 p.

Ponce, S. L. Water quality monitoring programs. WSDG Technical Paper 00002. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Watershed Systems Development Group; 1980. 68 p.

Progulske, D. R. Yellow ore, yellow hair, yellow pine. Bulletin 616. Brookings, SD: South Dakota State University, Agricultural Experiment Station; 1974. 169 p.

Pyne, Stephen J. Introduction to wildland fire: fire management in the United States. New York: John Wiley and Sons; 1984. 455 p.

Pyne, Stephen J. Vestal fires and virgin lands: a historical perspective on fire and wilderness. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 254-262.

Robertson, W. B., Jr. A survey of the effects of fire in Everglades National Park. Everglades National Park, FL: U.S. Department of the Interior, National Park Service; 1953. 169 p. Mimeo.

Roe, Arthur L.; Amman, G. D. The mountain pine beetle in lodgepole pine forests. Research Paper INT-71. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1970. 23 p.

Romme, William H. Vegetation in relation to elevation, topography, and fire history in a Wyoming mountain watershed. Laramie, WY: University of Wyoming; 1977. M.S. thesis.

Romme, W. H. Fire frequency in subalpine forests of Yellowstone National Park. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 27-30.

Romme, W. H. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs. 52: 199-221; 1982.

Romme, W. H.; Knight, D. H. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology. 62(2): 319-326; 1981.

Rothermel, R. C. A mathematical model for predicting fire spread in wildland fuels. Research Paper INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972. 40 p.

Rothermel, Richard C. Fire behavior systems for fire management. In: Proceedings, sixth conference on fire and forest meteorology; 1980 April 22-24, Seattle, WA. Washington, DC: Society of American Foresters; 1980: 58-64.

Rothermel, R. C. How to predict the behavior of forest and range fires. General Technical Report INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 161 p.

Rothermel, R. C.; Deeming, J. E. Measuring and interpreting fire behavior for correlation with fire effects. General Technical Report INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 4 p.

Rothermel, Richard C.; Reinhart, George E. Field procedures for verification and adjustment of fire behavior predictions. General Technical Report INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 25 p.

Rowe, J. S.; Scotter, G. W. Fire in the boreal forest. Quaternary Research. 3(3): 444-464; 1973.

Rowe, J. S.; Bergsteinsson, J. L.; Padbury, G. A.; Hermesh, R. Fire studies in the MacKenzie Valley. INA Publication QS-1567-000-EE-A1. ALUR 73-74-61. Ottawa, ON: Canadian Department of Indian Affairs and Northern Development; 1974. 123 p.

Sackett, S. S. An instrument for rapid, accurate, determination of fuel moisture content. Fire Management Notes. 41(2): 17-18; 1980.

St. John, Theodore V.; Rundel, Philip W. The role of fire as a mineralizing agent in a Sierran coniferous forest. Oecologia. 25: 35-45; 1976.

Sando, Rodney W. Natural fire regimes and fire management—foundations for direction. Western Wildlands. 4(4): 34-42; 1978.

Schiff, A. L. Fire and water: scientific heresy in the Forest Service. Cambridge, MA: Harvard University Press; 1962. 225 p.

Schirge, G. U.; Penderis, A. H. Fire in South African ecosystems: an annotated bibliography. South African National Scientific Programmes. Report No. 33. Pretoria, South Africa: Council for Scientific and Industrial Research; 1978. 114 p.

Schmidt, R. L. Factors controlling the distribution of Douglas-fir in coastal British Columbia. Quarterly Journal of Forestry. 54: 156-160; 1960.

Sellers, Robert E.; Despain, Don G. Fire management in Yellowstone National Park. In: Proceedings, Tall Timbers fire ecology conference No. 14 and Intermountain Fire Research Council fire and land management symposium; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station; 1976: 99-113.

Show, S. B.; Kotok, E. I. The role of fire in California pine forests. Bulletin 1294. Washington, DC: U.S. Department of Agriculture; 1924. 80 p.

Show, S. B.; Kotok, E. I. The determination of hour control for adequate fire protection in the major cover types of the California pine region. Technical Bulletin 209. Washington, DC: U.S. Department of Agriculture, Forest Service; 1930. 47 p.

Simard, A. J. The Mack Lake Fire. Fire Management Notes. 42(2): 5-6; 1981a.

Simard, Albert J. The modeling process. In: Computer modeling: its application in fire management: Proceedings of the symposium; 1981 October 20-22; Salt Lake City, UT. Missoula, MT: Intermountain Fire Council; Logan, UT: Utah State University; 1981b: 1-14.

Smith, Craig S. A 4,300 year history of vegetation, climate, and fire from Blue Lake, Nez Perce County, Idaho. Pullman, WA: Washington State University; 1983. 86 p. M.S. thesis.

Soeriaatmadja, R. E. Fire history of the ponderosa pine forest of the Warm Spring Indian Reservation, Oregon. Corvallis, OR: Oregon State University; 1966. 123 p. Dissertation. [Diss. Abstr. Int. 27: 2612-B.]

Spurr, S. H. The forest of Itasca in the nineteenth century as related to fire. Ecology. 35: 21-25; 1954.

Stoddard, H. L. Use of controlled fire in southeastern upland game management. Journal of Forestry. 33(3): 346-351; 1935.

Stone, E. C.; Grah, R. F.; Zinke, P. J. Preservation of the primeval redwoods in the Redwood National Park, part I. American Forests. 78: 50-55; 1972.

Stuart, John David. Stand structure and development of a climax lodgepole pine forest in south-central Oregon. Pullman, WA: Washington State University; 1983. 212 p. Dissertation.

Stuart, J. D.; Geiszler, D. R.; Gara, R. I.; Agee, J. K. Mountain pine beetle scarring of lodgepole pine in south-central Oregon. Forest Ecology and Management. 5: 207-214; 1983.

Suffling, Roger; Molin, Joseph D.; Smith, Brian. Trappers and the forest industry: the case of northwestern Ontario. Final report prepared for the Ontario Royal Commission on the Northern Environment under University of Waterloo Research Institute Contract 903-03. 1980. 79 p. Unpublished.

Swain, A. M. A history of fire and vegetation in northeastern Minnesota as recorded in lake sediments. Quaternary Research. 3(3): 383-396; 1973.

Swetnam, Thomas W.; Dieterich, John H. Fire history of ponderosa pine forests in the Gila Wilderness, New Mexico. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 390-397.

Tande, G. F. Fire history and vegetation pattern of coniferous forests in Jasper National Park, Alberta. Canadian Journal of Botany. 57: 1912-1931; 1979.

Taylor, D. L. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. Laramie, WY: University of Wyoming; 1969. 320 p. Dissertation.

Taylor, Dale L.; Herndon, Alan. Impact of 22 years of fire on understory hardwood shrubs in slash pine communities within Everglades National Park. South Florida Research Center Report T-640. Everglades National Park, FL: U.S. Department of the Interior, National Park Service; 1981. 30 p.

Terasmae, J. Postglacial chronology and forest history in the northern Lake Huron and Lake Superior regions. In: Cushing, E. J.; Wright, H. E. Jr., eds. Quaternary paleoecology: Proceedings, VII congress of the International Association of Quaternary Research. New Haven, CT: Yale University Press; 1967: 45-58.

U.S. Department of Agriculture, Forest Service. Chapter 2320, Wilderness and Primitive Areas. Forest Service Manual, Amendment 93. Washington, DC: U.S. Department of Agriculture, Forest Service; 1985.

Vankat, J. L. Vegetation change in Sequoia National Park, California. Davis, CA: University of California; 1970. 197 p. Dissertation.

Vankat, John L.; Major, Jack. Vegetation changes in Sequoia National Park, California. Journal of Biogeography. 5: 377-402; 1978.

Van Wagner, C. E. Height of crown scorch in forest fires. Canadian Journal of Forest Research. 3: 373-378; 1973.

Van Wagner, C. E. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7: 23-34; 1977.

Van Wagner, C. E. Age-class distribution and the forest fire cycle. Canadian Journal of Forest Research. 8: 220-227; 1978.

Van Wagner, C. E. Personal letter to the author, San Francisco, CA. 1978.

Van Wagner, C. E. Forest fire research in the Canadian Forestry Service. Information Report PI-X-48. Chalk River, ON: Agriculture Canada, Canadian Forestry Service; 1984. 45 p.

Van Wagner, C. E. Personal letter to the author, Missoula, MT. 1985.

Van Wagner, C. E.; Methven, I. R. Discussion: two recent articles on fire ecology. Canadian Journal of Forest Research. 8: 491-492; 1978.

van Wagtendonk, J. W. Fire and fuel relationships in mixed conifer ecosystems of Yosemite National Park. Berkeley, CA: University of California; 1972. 164 p. Dissertation.

van Wagtendonk, J. W. Refined burning prescriptions for Yosemite National Park. Occasional Paper No. 2. Washington DC: U.S. Department of the Interior, National Park Service; 1974. 21 p.

van Wagtendonk, J. W. Wilderness fire management in Yosemite National Park. In: Proceedings of the 14th biennial wilderness conference; Sierra Club and National Audubon Society. Boulder, CO: Westview Press; 1978: 324-335.

van Wagtendonk, Jan W. Fire suppression effects on fuels and succession in short-fire-interval wilderness ecosystems. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 119-126.

van Wagtendonk, J. W.; Bancroft, L.; Ferry, G.; [and others]. Prescribed fire monitoring and evaluation guide. Washington, DC: National Wildfire Coordinating Group, Prescribed Fire and Fire Effects Working Team; 1982. 16 p.

van Wagtendonk, Jan W.; Botti, Stephen J. Modeling behavior of prescribed fires in Yosemite National Park. Journal of Forestry. 82(8): 479-484; 1984.

Veirs, S. D., Jr. The influence of fire in coast redwood forests. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 93-95.

Veirs, Stephen D., Jr. Coast redwood forest: stand dynamics, successional status, and the role of fire. In: Forest succession and stand development research in the Northwest: Proceedings of the symposium; 1981 March 26; Corvallis, OR. Corvallis, OR: Forest Research Laboratory, Oregon State University; 1982: 119-141.

Viereck, L. S. Wildfire in the tiaga of Alaska. Quaternary Research. 3: 465-495; 1973.

Vogl, Richard J. Fire and plant succession. In: Role of fire in the Intermountain West. Missoula, MT: Intermountain Fire Research Council; 1970: 65-75.

Wagener, Willis W. Past fire incidence in Sierra Nevada forest. Journal of Forestry. 59: 739-748; 1961.

Weaver, Harold. Fire as an ecological and silvicultural factor in the ponderosa pine region of the Pacific slope. Journal of Forestry. 41: 7-15; 1943.

Weaver, Harold. Fire as an ecological factor in Southwestern ponderosa pine forests. Journal of Forestry. 49: 93-98; 1951.

Weaver, Harold. Fire as an enemy, friend, and tool in forest management. Journal of Forestry. 53: 499-504; 1955.

Weaver, Harold. Ecological changes in the ponderosa pine forest of Cedar Valley in southern Washington. Journal of Forestry. 57: 12-20; 1959.

Weaver, Harold. Fire and its relationship to ponderosa pine. In: Proceedings, Tall Timbers fire ecology conference No. 7; 1967 November 9-10; Lake County, CA. Tallahassee, FL: Tall Timbers Research Station; 1967: 127-149.

Weaver, Harold. Effects of fire on temperate forests: western United States. In: Kozlowski, T. T.; Ahlgren, C. E., eds. Fire and ecosystems. New York: Academic Press; 1974: 279-319.

Weeks, Nancy C. Wildfire cycling in the natural environment: a key to paleoclimatic reconstruction. St. Catharines, ON: Brock University; 1976. 97 p. B.S. thesis.

Wein, Ross W.; MacLean, David A., eds. The role of fire in northern circumpolar ecosystems. SCOPE 18. New York: John Wiley & Sons; 1983. 322 p.

Wellner, Charles A. Fire history in the northern Rocky Mountains. In: Role of fire in the Intermountain West. Missoula, MT: Intermountain Fire Research Council; 1970: 42-64.

Wells, C. G.; Campbell, R. E.; DeBano, L. F.; [and others]. Effects of fire on soil: a state-of-knowledge review. General Technical Report WO-7. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 34 p.

West, Neil E. Successional changes in the montane forest of the central Oregon Cascades. American Midland Naturalist. 81: 265-271; 1969.

Westman, Walter E. Measuring the inertia and resilience of ecosystems. Bioscience. 28(11): 705-710; 1978.

The Wilderness Society. Wilderness: an anniversary issue. Wilderness. 48(167); 1984. 48 p.

Worf, William A. Wilderness management: a historical perspective on the implications of human-ignited fire. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings—symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 276-282.

Wright, H. E., Jr.; Heinselman, M. L. The ecological role of fire in natural conifer forests of western and northern North America: introduction. Quaternary Research. 3: 317-328; 1973.

Wright, H. A.; Bailey, A. W., eds. Fire ecology: United States and southern Canada. New York: John Wiley and Sons; 1982. 501 p.

Zager, Peter; Jonkel, Charles; Habeck, James. Logging and wildfire influence on grizzly bear habitat in northwestern Montana. International Conference on Bear Research and Management. 5: 124-132; 1980.

AUTHOR

Bruce M. Kilgore
Chief, Division of Natural Resources and Research
National Park Service, Western Region
U.S. Department of the Interior
San Francisco, CA 94102

AIR QUALITY AND WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

R. Kent Schreiber
James R. Newman

ABSTRACT

Air quality is an important component of the wilderness concept. In wildernesses that are designated Class I lands, "air quality-related values" are protected by the Clean Air Act and its amendments. In addition, all wilderness, as defined by the Wilderness Act, is to be protected and managed so as to preserve its unique character, including its air resource. This paper provides an overview of the air quality legislation pertaining to wilderness, a brief summary of the types of air quality conditions potentially affecting wildernesses, and a discussion of research efforts that have addressed air quality and its influence on aquatic and terrestrial ecosystems. A limited survey of Federal land managers responsible for wilderness areas provides insight to the current ecological understanding, research, and information needs required to adequately protect and maintain these primitive areas. The authors suggest that a well-developed system of air quality-related values applicable to wildernesses is critical for proper protection.

INTRODUCTION

Congress has defined "wilderness" in the Wilderness Act of 1964 (Public Law [PL] 88-577) as "...an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain..." and "an area of undeveloped Federal land retaining its primitive character and influence, without permanent improvements of human habitation, which is protected and managed so as to preserve its natural conditions...." Implied in this definition is the preservation of a very transient but vital component of the wilderness—its air quality.

Earlier papers in this conference have discussed various values of wildernesses. These values, for the most part, include those characteristics associated with pristine conditions. Maintaining the pristine condition of air quality in wildernesses may be impossible. Even in the most remote regions of the world, evidence of contamination by global circulation of airborne pollutants has been found (Davidson and others 1985). For example, the long-range transport of acidifying pollutants from England and central Europe and subsequent ecological effects in Scandinavia are well documented. Although development affecting air quality can be controlled within wildernesses, control of outside development that contributes to a degradation of air quality is only partially successful. The Clean Air Act and its amendments protect some wildernesses and portions of others only from certain kinds of emission sources. Wilderness areas are currently affected by regional air pollution such as acid rain or oxidants. Control of these pollution sources when air quality and other wilderness components are observed to be adversely affected is a major point of controversy and discussion (for example, OTA 1984).

Air quality is influenced by both natural and human-made sources. Natural events such as forest fires, volcanic eruptions, geothermal activities, and biogenic sources can lower air quality in wildernesses. Forest fires can contribute locally and regionally significant amounts of particulates, carbon dioxide, and hydrocarbons (Smith 1981). The major influence on air quality in most of these areas, however, is from human-made sources. A number of air pollutants have affected, or are suspected to affect, wilderness conditions. These can be grouped into three major types: photochemical oxidants, including secondary pollutants such as ozone; particulates, such as trace elements, organic compounds, and radioactive particles; and acidifying pollutants, including the primary gaseous emissions such as sulfur dioxide and nitrogen oxides (Peterson and Adler 1982). The origin of these major pollutant types can be point sources (for example, industrial facilities such as powerplants and smelters) or nonpoint regional sources (such as urban areas, industrial complexes, and mobile sources related to transportation). The effects of air pollution can be composed of either single or multiple factors. Multiple effects can involve pollutant-pollutant interactions as well as pollutant-natural stress factor considerations, such as dramatic insect population changes.

The components of wildernesses that can be affected by air pollution include whole ecosystems (lake acidification); certain properties of ecosystems (nutrient cycling); and the biotic and abiotic components of ecosystems (plants and soils). Air pollution can also affect multiple ecosystems such as the lakes and forests around Sudbury, ON, Canada, which have been impacted by emissions from a large smelter.

Our purpose is to provide a brief overview of past and present air quality legislation and research related to the protection and management of wildernesses. In addition, we will identify some major air quality wilderness research themes for the future.

In preparing this overview we have relied on a number of studies demonstrating key wilderness-air quality issues as well as summaries that review ecological effects of air pollution relative to various wilderness components. For example, Smith's book, *Air Pollution and Forests* (Smith 1981), the U.S. Fish and Wildlife Service's series on air pollution and acid rain, the U.S. and Canadian Working Group report on transboundary air pollution, and the Environmental Protection Agency's critical assessment document of acidic deposition (Altshuller and Linthurst 1984) each provide detailed discussion on air quality and its relationship to biological systems also found in wilderness areas. A number of major ecological research studies on air pollution, such as the Colstrip Project in Montana (Lauenroth and Preston 1984) and the Hubbard Brook Ecosystem Project in New Hampshire, have also contributed significantly to our understanding and appreciation of a whole system's response to air pollution. Manual and computer literature searches, focusing on references published since 1981, involved the following data bases: BIOSIS, NTIS, AGRICOLA, POLLUTION ABSTRACTS, ENVIRONLINE, and to a limited extent, SCISEARCH. *Ecological Abstracts* and the *Acid Precipitation Digest* were also manually searched. Halpin (1977) provides a good introduction to the air pollution literature. To complement this information, we conducted a limited survey of investigators and Federal agencies regarding air pollution research with application to wildernesses. Federal land managers of wilderness lands with special air quality protection (Class I) administered by the National Park Service, Fish and Wildlife Service, and Forest Service were contacted to determine ongoing or planned air quality-related research programs. Future research needs were also assessed.

AIR QUALITY LEGISLATION AND WILDERNESSES

The oil crisis of the early 1970's forced the Nation's attention on the tenuous availability of this supply of energy and pushed the development and use of our own fossil fuel resources. The role of fossil fuels in meeting the country's energy demands was projected to increase exponentially. This search for energy independence introduced a number of activities with impacts or potential impacts to wildernesses. In addition to the imminent threat of exploration and development in areas adjacent to wildernesses, the increased use of fossil fuels, particularly coal, accelerated atmospheric loading of combustion byproducts. Coupled with this type of airborne pollution were the continuing contributions of trace metals and other contaminants from smelting of metallic ores and the release of trace organics and other chemicals from various industrial processes (Soholt and Wiedenbaum 1981; Miller 1981).

The emissions from both point and nonpoint sources are capable of being carried long distances by prevailing winds and undergoing various chemical transformations in the process. This delivery system allows the transfer of toxic materials to surface receptors in wildernesses far removed from actual pollution-generating sites or regions. Research in Scandinavia focused attention on effects of a specific form of air pollution, a rediscovered phenomenon called "acid rain" (Drablos and Tollan 1980; Swedish Ministry of Agriculture 1982), and evidence was accumulating for similar impacts in the United States (Dochinger and Seliga 1976; Pfeiffer and Festa 1980).

It was in this time of environmental awakening in the 1960's and 1970's that a number of new pieces of legislation and revisions to old laws related to air quality were created. Incorporated in this important legislative activity was the concept of air as a resource requiring protection and the implementation of standards to maintain certain air quality standards in designated areas.

The Air Pollution Control Act of 1955 (PL 84-145, 69 Stat. 322), the Clean Air Act of 1963 (PL 88-206, 77 Stat. 392), and the Air Quality Act of 1967 (PL 90-148, 81 Stat. 485, as amended) were early attempts for regulatory action (Avery and Schreiber 1979). However, it was the 1970 Clean Air Amendments that provided the strong Federal role in establishing and enforcing ambient air standards. These amendments designated air quality control regions, provided air quality criteria and pollution control techniques information for major pollutants, and established primary and secondary National Ambient Air Quality Standards (NAAQS) for criteria pollutants. Criteria are issued to assist with decisions about the need for control of a given pollutant and for the development of air quality standards to govern the pollutant. Primary standards are those necessary for the protection of "public health"; secondary standards are those that provide a level of air quality that protects the "public welfare" from any known or anticipated adverse effects (Avery and Schreiber 1979). It should be noted that "public welfare" includes, but is not limited to, effects on soils, water, vegetation, animals, wildlife, and visibility—all values important to the concept of wilderness.

National air quality goals also involve Federal standards for control of airborne pollutants. For example, New Source Performance Standards (NSPS) deal with new stationary sources of emissions, such as powerplants. Title II legislation set standards for motor vehicle emissions and fuels and the National Emission Standards for Hazardous Pollutants (NESHAP) covered specific pollutants such as asbestos. The Federal land manager's role became one of complying with the standards and being involved with the permitting process for projects that might adversely affect the air resource.

Pollutants currently covered by the NAAQS include sulfur oxides, particulates, carbon monoxide, photochemical oxidants, nitrogen dioxides, and lead (table 1). A major share of the responsibility for meeting the goals of NAAQS is placed on the States by requiring their development of individual State Implementation Plans (SIP's). These plans address the timely attainment and maintenance of NAAQS. Areas that meet the standards (attainment) or that are unclassifiable are considered "clean air" areas. The SIP's require maintenance plans to assure no violation of NAAQS and plans to prevent any significant deterioration of these areas. The concept of prevention of significant deterioration (PSD) was implied in the 1970 amendments and became a major part of the 1977 amendments (PL 95-95, 91 Stat. 731, Part C). Significant deterioration is defined by the use of baseline levels and increments for criteria pollutants. The baseline level is the actual concentration that exists within the clean air areas at a fixed time and the increment is the additional concentration of an air pollutant that can be added to the area. The effect of the baseline-increment concept is that the PSD ceiling varies from place to place. The allowable increment in dealing with the PSD permit application, then, is the margin between baseline and the lower of either the

Table 1.—National primary and secondary ambient air quality standards

	Air quality standards			
	Primary		Secondary	
	Annual mean	Maximum concentration (allowed once yearly)	Annual mean	Maximum concentration (allowed once yearly)
	Micrograms/m³			
Sulfur oxides (SO_x) (measured as SO_2)	80	365 (during 24 hours)	—	1,300 (during 3 hours)
Particulates	75	260 (during 24 hours)	60	150 (during 24 hours)
Carbon monoxide (CO)	—	10 milligrams/m³ (during 8 hours) 40 milligrams/m³ (during 1 hour)		Same as primary standard
Photochemical oxidants	—	160 (during 1 hour)		Same as primary standard
Nitrogen dioxide (NO_2)	100	—		Same as primary standard
Lead	—	1.5 (averaged over calendar quarter)		Same as primary standard

NAAQS or full increment. It is this component of the clean air legislation that has particular relevance to wildernesses. Under the 1977 amendments, lands were classified as one of three categories: Class I—where only minor air quality deterioration was permitted; Class II—where deterioration normally accompanying moderate, well-controlled growth was acceptable; and Class III—where a rise in pollution levels up to the NAAQS was considered acceptable (Avery and Schreiber 1979). Within this land classification scheme, wildernesses exceeding 5,000 acres (2 024 ha) and established before August 1977 were automatically designated Class I areas. Remaining wildernesses were assigned to Class II but were to be subject to possible redesignation. For wildernesses established after August 1977 and exceeding 10,000 acres (4 049 ha) the redesignation was limited to either Class I or II.

The Federal official managing these Class I areas has the "affirmative responsibility" to protect the air quality-related values (AQRV) and, along with the regulatory authority of the Environmental Protection Agency, to consider whether or not a proposed emitting facility will adversely affect those values (Avery and Schreiber 1979). Visibility is specifically addressed in the amendments, but other aspects such as acid rain and damage to flora and fauna are also considered under the term AQRV. The Federal land manager must therefore be knowledgeable of the air quality-related values on the Class I lands and their sensitivity to air pollution. Although wildernesses not currently designated Class I are not provided this protection under the Clean Air Act, the management requirements of the Wilderness Act may be interpreted to include similar restrictions. For example, in some Forest Service regions, to afford the best protection of air quality in wilderness areas, all wilderness is treated as if it is Class I so as to protect it from all human-made changes including air pollution (Haddow 1984).

These laws and standards demonstrate the importance of air quality to the general public and our growing concern for monitoring and protecting the air resource.

In 1969, the National Wildlife Federation (NWF) incorporated air, as well as other natural resources, as part of an index to annually assess the national environmental quality and to provide a subjective analysis of trends (Kimball 1969). Air pollution was considered the most serious threat to environmental quality in the first assessment. There was also an indication of a downward trend in air quality in spite of the fact that air pollution control laws existed in 46 of the 50 States at the time. By 1975, air quality had improved somewhat, the index had turned, and the trend was upward.

Ten years after the first NWF index there was evidence that the air was in fact cleaner due to the Federal Air Pollution Standards. Between 1975 and 1983 sulfur oxide emissions were reduced 19 percent, and air in general contained 36 percent less sulfur dioxide and 20 percent fewer suspended particles. Electric utilities had spent $67 billion on air pollution control, primarily to reduce sulfur emissions. Unfortunately, at the same time the increasing number of monitoring stations (2,000 in 1970 compared to 6,500 in 1975) provided evidence that air in rural areas was being further degraded. The transport of pollutants from urban point sources to remote areas eventually became one of the major concerns in the acid precipitation controversy of the 1980's. By 1977, damages to health from air pollutants were estimated at $10 billion annually, and visibility in some remote areas had declined as much as 20 percent. The first indications of problems with acid rain in remote areas such as the Adirondacks were coming to light at the same time economic growth had slowed and there were increasing prospects for relaxing current standards. By 1981, when the Clean Air Act was up for revision, the acid rain controversy was a major issue. Of particular concern was the damage or potential for damage in remote pristine ecosystems such as the Nation's wildernesses. The current Clean Air Act is designed primarily to address local effects and does not effectively deal with long-range transport and transformation of air pollutants. With the growing body of research, including reports from the prestigious National Academy of Science (for example, National Academy of Science 1981), the public has expressed a continuing interest and support for strong regulatory controls for improved air quality. Although no decision has yet been made on the best way to control acid rain, the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act) established a Federal interagency task force to implement a comprehensive research program. The program's objectives are to identify the causes and sources of acid precipitation; evaluate environmental, social, and economic effects; and take action to limit or eliminate the sources and remedy the harmful effects (Interagency Task Force 1982). This 10-year National Acid Precipitation Assessment Plan (NAPAP) provides annual reports to the President and Congress and biannual assessments of the status of acid precipitation impacts on the Nation's resources. Provisions for Class I lands in the Clean Air Act and its amendments provide the only current legislation on acid rain.

AIR QUALITY BIOMONITORING AND WILDERNESS AREAS

As with other types of pollution, the need to collect information indicating the condition and trends in the health of ecosystems and their components exposed to air pollution has led to development and use of air pollution biomonitoring. Three types of air quality biomonitoring approaches are in use today and are part of monitoring in wildernesses: air quality-related values, bioindicators, and biosphere reserves. The first type is a biomonitoring approach, mandated by air quality legislation, while the latter two are general biomonitoring approaches using single species or whole ecosystems as biomonitors. As previously discussed, the Clean Air Act and its amendments of 1977 give special attention to potential ecological effects in Class I lands, which include certain wildernesses. The Federal land manager has responsibility to review PSD permits for new sources that may affect these areas and to determine whether or not adverse impacts on the AQRV's of that Class I area will occur. The Department of the Interior has defined AQRV's as being: "...all those values possessed by an area except those that are not affected by changes in air quality and include all those assets of an area whose vitality, significance, or integrity is dependent in some way upon the air environment. These values include visibility, and those scenic, cultural, biological and recreational resources of an area that are affected by air quality" (Federal Register 1978). Currently, AQRV's are being further refined by agencies such as the Forest Service and the National Park Service. For example, the concept of "adverse" effects has been defined by the Rocky Mountain and Intermountain Regions of the Forest Service as "change" rather than just "damage" (Haddow 1984). Specific AQRV sampling protocols for particular ecosystems (for example, at high elevations) are being developed by the Forest Service (see papers by Fox and Haddow in this proceedings).

When identifying Class I area AQRV's, visibility is the only value to date that has received formal attention and use of standard assessment techniques. Ecological AQRV's have been developed on a case-by-case basis as Federal land managers have been requested to review PSD permits. In 1981, the Forest Service held a workshop on identifying and protecting AQRV's of the Flat Tops Wilderness in Colorado (Fox and others 1981). Specific AQRV theory along with identification of specific AQRV's were presented. For fish and wildlife AQRV's a matrix approach was used to identify and develop wilderness monitoring programs (Newman and others 1981). A hierarchical progression of AQRV's was proposed based on societal significance, wilderness management needs, and special species consideration. Primary pollutant interaction points or potential points of contamination were identified and, using this matrix analysis of potential effects, appropriate biomonitoring programs were suggested. More recently, the Forest Service has identified a number of wilderness attributes as values that can be affected by air quality and from these they have developed a number of specific AQRV indexes (table 2) that can be impacted, that is, changed from their natural state (Haddow 1984).

The importance of establishing AQRV's has been indicated in several recent cases concerning Class I refuges and parks and the potential impact of new sources of emissions. For example, an aluminum smelter with fluoride emissions, potentially affecting Cape Romain National Wildlife Refuge in South Carolina, and a powerplant and natural gas processing facility with SO_2 emissions, potentially affecting Theodore Roosevelt National Park and Lostwood National Wildlife Refuge in North Dakota, have required AQRV reviews. After AQRV analysis no "adverse" impact determinations were given by the Federal land managers although, based on modeling, some potential impact was predicted for the most sensitive AQRV's—lichens (Federal Register 1982).

Air pollution bioindicators have been proposed and used for a long time. The first uses were to protect human health. Miners, for example, took canaries into the mines to detect carbon monoxide. Bioindicators are useful for several reasons: they are indicative of an ecological response to given air quality conditions, they can indicate trends in ambient air quality conditions, and they provide correlations between physical-chemical measurements and ecological effects.

Air quality bioindicators can be of several types (Newman 1980):

1. Sentinel organisms—highly sensitive species whose response can act as an early warning signal to a particular pollutant;
2. Bioassay monitors—species with known life histories and known characteristic responses to a given pollutant;
3. Detectors—species found in an environment that show a reasonably characteristic response to a given air pollutant (not as diagnostic as bioassay monitors);
4. Thrivers—species whose presence or abundance indicates the occurrence of a particular pollutant or environmental condition associated with a pollutant; and
5. Accumulators—species that collect and accumulate an air pollutant in detectable quantities, thereby showing trophic accumulation.

Table 2.—Wilderness attributes identified by the Forest Service that are impacted by air quality and suggested indexes for determining change (from Haddow 1984)

Attribute					
Flora/fauna	**Soil**	**Water**	**Visibility**	**Odor**	**Cultural, archeological, geological**
Growth	Cation exchange capacity	pH	Contrast	Odor	Decomposition rate
Mortality	Base saturation	Total alkalinity	Visual range		
Reproduction	pH	Metal concentrations	Coloration		
Diversity	Structure	Anion and cation concentrations			
Visible injury	Metal concentration				
Succession					
Productivity					

In contrast to water pollution monitoring, no hierarchical system of bioindicators has been developed for air pollution monitoring. Presently for air quality studies, plants are probably the most developed bioindicator group. Higher plants used in monitoring have involved species ranging from crops and ornamental plants to naturally occurring trees and weeds (Heck 1966; Minnesota Environmental Quality Board 1984). Field surveys of plants have been the most common bioindicator approach. In this situation knowledge of the sensitivity and recognition of the symptoms exhibited by particular plant species are required. A large number of plants are used in the survey, and selection is dependent upon the observer's experience and preference. The National Park Service is surveying more than two dozen park lands using the responses of milkweed (*Asclepias*), white pine (*Pinus monticola*), and ponderosa pine (*Pinus ponderosa*) as indicators of ozone effects (Bennett 1985b). In another approach, "indicator gardens" consisting of different plants with defined responses to various pollutants have been used. Minnesota, using this approach with native species and supporting fumigation studies, has established seven sites at diverse locations for long-term monitoring (over 10 years) of air quality. Use of isolines of a plant with varying sensitivities has also been proposed. The use of bioindicator gardens has a number of advantages, including the ability to be colocated with air monitoring stations. In addition, the accessibility to the natural occurrence of known sensitive species may be difficult. Establishment of indicator gardens with these species in accessible locations is possible (Bennett 1985a).

The most widespread and probably best understood plant bioindicator system involves the use of lower plants. Lichens and bryophytes have been used as air pollution indicators in North America and Europe (Ferry and others 1973; LeBlanc and Rao 1975; Skye 1979). Because of a number of characteristics, they are especially suitable as pollutant monitors. Specifically, they are evergreen and slow growing, and, having no roots, they derive all their nutrients from air and rainfall. Because they lack stomata, they do not have the ability to control gas exchange. Also, these groups cannot shed pollutant-damaged structures as higher plants can.

Field surveys and transplant studies are employed in using lichens and mosses as bioindicators. Correlations between air quality and species presence, abundance, and absence have been developed from fumigation studies and observations of distribution with known ambient concentrations of pollutants (Minnesota Environmental Quality Board 1984). The National Park Service is sponsoring fumigation studies of lichens in several national parks and conducting lichen bioindicator surveys in both parks and monuments (Hale 1984; Bennett 1985b).

The reactions of lichens to toxic materials include changes in color, growth reduction, membrane leachage, and mortality. One particular response to air pollutant exposure is a weakening of the cell membrane and subsequent loss of vital electrolytes. This physiological alteration can be used to establish relationships between pollutants and lichen species. A scale of responses can be developed by testing different species' electrical conductivity after exposure to varying pollution regimes. This technique is currently being evaluated in a lichen monitoring system in Zion National Park and the Navajo National Monument in a project jointly sponsored by the National Park Service and the Bureau of Land Management. Lichen biomonitoring has also been proposed for the Bridger Wilderness in Wyoming (Hale 1984) and is currently being conducted for sulfur at Isle Royale, Theodore Roosevelt, Everglades, Shenandoah, and Great Smoky Mountains National Parks (Bennett 1985b).

Using animals as ecosystem indicators of air pollution effects has been proposed (Newman 1975; Newman and others 1981) and has considerable supporting evidence (Grodzinski and Yorks 1981; Newman and Schreiber 1984). Animal species and populations can act as indicators of biotic and abiotic responses of aquatic and terrestrial ecosystems to air pollution. The responses of animals to air pollution have been indicative of altered community energetics and structure, ecosystem life history, chemical cycling, ecosystem genetics, and homeostasis. Animals as biological receptors of air pollutants show not only direct effects at consumer levels but also indicate indirect effects at producer and decomposer levels. For example, in Europe the house martin, an insectivorous bird, has been found to be a very good indicator of both point source and regional air pollution (Newman and others 1985). Animals are excellent bioaccumulators of certain heavy metals. Certain tissues of birds (feathers) and mammals (hair, antlers) concentrate these metals and can be easily collected and analyzed (Newman 1975; Jenkins 1980).

A third type of biomonitoring approach is the use of large ecosystems or landscapes as biosphere reserves. The United Nations Conference on the Human Environment in Stockholm in 1972 recommended establishment of this type of monitoring, research, evaluation, and information exchange. This program has become known as the Global Environmental Monitoring System (GEMS). As a part of GEMS, biosphere reserves were established. The biosphere reserves are seen as areas where background data on pollutant levels can be obtained, and they serve as early warning sites for monitoring global pollution trends as well as other environmental uses (Wiersma and others 1978). Presently there are 243 biosphere reserves in 65 countries around the world. This biosphere reserve program is coordinated by the Man and Biosphere (MAB) of UNESCO (Anonymous 1985). Wiersma and colleagues (Wiersma and others 1978; Wiersma and Brown 1980; Wiersma 1985) discuss monitoring considerations and some results in determining background concentrations of trace metals in several proposed U.S. biosphere reserves, including Yellowstone, Sequoia-Kings Canyon, Olympic, and Great Smoky Mountains National Parks. Presently a biosphere reserve program is being monitored in Olympic National Park in Washington. Trace element monitoring, using filters, impactors, and teflon plates, is being conducted at several locations in the park (Davidson and others 1985). Six ecosystem parameters are also being measured: moss and lichen productivity, leaf litter fall, litter decay rates, nutrient flux in the soil, and needle population structure (Franklin 1985).

ECOLOGICAL EFFECTS OF AIR QUALITY CONDITIONS

Reported Effects on Ecosystems

From the perspective of wilderness integrity, the effects of air pollution on the ecosystem are of utmost importance. Although much attention has been given to the effects of air pollution on ecosystem components such as single species vegetation studies, past and current effects on whole ecosystems are recognized (Guderian 1977; Miller 1980; National Academy of Science 1981; Peterson and Adler 1982; Newman and Schreiber 1984). Ecosystem effects have been reported from point sources (Carlson and Dewey 1971; Lauenroth and Preston 1984; Nriagu 1984) as well as regional sources (U.S. EPA 1983). Much of the reported information about the effects of air pollution on ecosystems involves studies on forest ecosystems, which table 3 summarizes (Smith 1981; Grodzinski and others 1984; McLaughlin 1985). The quality and quantity of the information depends on the air contaminant (tables 4 and 5). Much less information is available on ecosystem effects on alpine-subalpine, grassland, chaparral, and desert ecosystems (Newman and Schreiber 1984).

Based on the information available, scientists have attempted to characterize the responses of ecosystems to air pollution (Woodwell 1970; Auerbach 1981; Ecological Society of America 1981; Smith 1981; Suter 1981). The proposed responses can be divided into two groups of hypotheses:

1. Air pollution effects can be characterized as causing a reversal of ecosystem successional processes, or
2. Air pollution effects can be characterized as a series of stages of stress to the ecosystem.

Table 3.—Summary of major air pollutant impacts of forest ecosystems in the United States (from Smith 1981)

Region	Forest type	Air pollution impact
Eastern U.S.	Boreal forest	Primary impact from acid deposition, also heavy metal input
	Northern hardwood forest	Sulfur pollution and heavy metal particulates, in southern and western portions photochemical oxidants increasing problem
	Central forest (oak and hickory)	Sulfate and acid precipitation along with trace metals
	Southern forest (oak-pine and longleaf-loblolly-slash)	Least impacted of the forests by sulfur and trace metals
	Tropical forest	Certain areas affected by oxidants and particulates
Western U.S.	Western montane forest	Point source SO_2, F, and trace metal impacts; oxidants in California
	Subalpine forest	Minimal impacts
	California woodlands	Oxidants and particulates
	Southwestern woodlands	Minimal SO_2 and particulate loading

Table 4.—Relative strength of evidence (quantity or quality)[1] available to support forest ecosystems interaction with regional[2] air pollutants (from Smith 1985)

	Air contaminants			
Ecosystem process and component perturbation	**Oxidants**	**Trace metals**	**Acid deposition**	**Total**
I. Nutrient Cycling				
1. Increase nutrient availability				
a. Increase input (fertilization)	0	1	2	3
b. Increase soil weathering	0	0	1	1
2. Decrease nutrient availability				
a. Reduce litter decomposition	0	4	1	5
b. Increase soil acidification	0	0	2	2
c. Increase soil (cation) leaching	0	0	2	2
d. Decrease microbial symbiosis	0	3	1	4
II. Primary Producers (trees)				
1. Reproductive physiology				
a. Reduce flowering	1	1	0	2
b. Reduce pollen production, metabolism	2	1	1	4
c. Reduce cone, seed set	2	0	0	2
d. Reduce seedling survival	3	3	1	7
2. Foliar physiology				
a. Reduce photosynthesis	4	1	0	5
b. Increase (cation) leaching	0	0	2	2
c. Increase necrosis	4	2	0	6
3. Root physiology				
a. Decrease water, nutrient uptake	0	1	1	2
b. Increase necrosis	0	1	2	3
4. Reduce tree growth	4	1	1	6
III. Consumers				
1. Arthropod pest activity				
a. Increase	4	0	0	4
b. Decrease	0	0	0	0
2. Microbial pathogen activity				
a. Decrease	1	2	0	3
3. Other pest activity (viruses, bacteria, nematodes, mistletoes, weeds)				
a. Increase	0	0	0	0
b. Decrease	0	0	0	0
4. Wildlife (bird, mammal) activity				
a. Reduce food	2	0	0	2
b. Reduce habitat	2	0	0	2
c. Increase morbidity or mortality	0	2	0	2
IV. Ecosystem Succession-Species Composition (cause alteration)	4	1	0	5
V. Ecosystem Productivity (increase or decrease biomass accumulation)	4	0	0	4
Total	41	25	18	84

[1] Evidence scale:
0 = extremely limited evidence or hypotheses only
1 = slight evidence
2 = more evidence
3 = greater evidence
4 = considerable evidence including field evidence.

[2] Exclusive of local air pollution effects within several kilometers of point sources.

Table 5.—Classes of interaction of air pollution and temperate forest ecosystems (modified from Smith 1981)

Class of interaction	Forest soil and vegetation: activity and response	Ecosystem consequence and impact
Class I	1. Forest soils and vegetation particulate and gaseous contaminants to the atmosphere	1. Atmospheric burden of contaminants from anthropogenic sources supplemented by forest additions—scale may be local, regional, or global
	2. Forest soils and vegetation remove particulate and gaseous contaminants from the atmosphere	2. Air contaminants transferred from the atmosphere to the biosphere, forest ecosystems supplement natural removal mechanisms
	3. No or minimal alteration of structure or metabolism forest soils or vegetation	3. No adverse ecosystem change evident
Class II	1. Forest tree reproduction, alteration, or inhibition	1. Altered species composition
	2. Forest nutrient cycling, alteration a. Reduced litter decomposition b. Increased plant leaching, soil leaching, and soil weathering c. Disturbance of microbial symbioses	2. Reduced growth, less biomass
	3. Forest metabolism, alteration a. Decreased photosynthesis b. Increased respiration	3. Reduced growth, less biomass
	4. Forest stress, alteration a. Phytophagous insects, increased or decreased activity	4. Altered ecosystem stress; increased or decreased insect infestations
	b. Microbial pathogens, increased or decreased activity	Increased or decreased disease epidemics
	c. Foliar damage increased by direct air pollution influence	Reduced growth, less biomass, altered species composition
Class III	1. Severe morbidity, excessive foliar damage	1. Dramatic change in species composition, reduced biomass, increased erodibility, nutrient attrition, altered microclimate and hydrology
	2. Mortality	2. Forest simplification or destruction

Woodwell (1970) discussed experiments at Brookhaven National Laboratory in New York on the effects of ionizing radiation on the structure and function of forest ecosystems. He proposed the theory that air pollution causes the same pattern of destruction of an ecosystem as does radiation. In essence, what he showed was that with constant bombardment by radiation there was a reversal of the process of ecosystem development with a regression to early developmental stages. The degree of reversal depended upon the amount and duration of exposure to the pollutant. Initially, growth was retarded in trees, especially conifers, with widespread crown killing. Eventually, all the trees died, including the broadleaf trees, followed by the shrubs, herbs, and grasses. There were distinct zones radiating out from the pollution source that reflected the degree of pollution exposure. These zones were also similar to the various stages in development of the exposed oak-pine forest.

The general conclusions drawn from Woodwell's study regarding the effects of pollution on ecosystems are:

1. There is a common pattern of destructive change in terrestrial ecosystems.
2. These changes are similar to those found along natural gradients of increasingly severe conditions. In particular, community structure dominated by trees is reduced to one dominated by shrubs. With more severe conditions there is a reduction from shrubs to low-growing plants, these plants being recognized as pioneer or generalist types. Finally, with increasing severity there is total removal of vegetation.
3. The change in structure is toward simplification or a decrease in spatial heterogeneity.
4. Species richness (both animals and plants) is reduced.
5. The ratio of gross production to community respiration exceeds one.
6. Fewer inorganic nutrients are tied up in the biota and more are lost from the system because of pollution.
7. There is an increased effect of the physical environment on the biotic community.

Two notable examples supporting this theory of air pollution damage to ecosystems are found in Tennessee and Canada. The first case is in an area of southeastern Tennessee called Copperhill (Haywood 1905, 1910; Hursh 1948). It is an area characterized by an oak-pine forest.

Mining for copper started in the 1850's, but the ore was not processed in the area until open hearth smelting began around 1890. The major air pollutant was SO_2, with the greatest production occurring between 1890 and 1895. By 1910 a typical pattern of a destroyed ecosystem developed and still persists today. In 1948, the area was characterized by a bare zone 10.5 mi^2 in size. The area is still increasing in size due to severe erosion. Surrounding the bare zone is a belt of grassland 1 to 2 miles wide comprising 17,000 acres. Erosion gullies from the bare zone constantly undercut the grassland. Surrounding the grassland zone is a mixed zone of grass, shrubs, and trees comprising some 30,000 acres. Those trees present are partially damaged. Beyond this zone is the natural undisturbed forest. The interior zones showed the characteristics of early succession both in terms of plant structure and ecological features. The first plants lost were white pines, then the hardwood trees, shrubs, and finally the grasses.

The second example of similar ecological change is from Wawa, ON, Canada, in a forested area surrounding an iron smelter (Gordon and Gorham 1963; Gorham 1970). The damage at Copperhill was circular. At Wawa the pattern of damage is elongate and conforms to the local wind patterns. Structural damage to the plants is seen 20 miles from the smelter. It is considered severe within 11 miles and very severe within 5 miles of the smelter. The plant species richness decreases from 20 to 40 species per square yard within 10 miles of the smelter to 0 to 1 species per square yard within 2 miles of the smelter. Again, the same pattern of change is present. The most sensitive species, the conifers, disappear first. As a matter of fact, no white pine seedlings were found within 30 miles of the smelter. The categories of damage reflect the pattern of successional reversal:

Moderate—tip killing and crown thinning, extensive in overstory; little damage to understory.
Considerable—overstory almost completely killed, a few white birch and white spruce alive but dying; understory dense but with tip killing.
Very severe—ground vegetation nearly all gone, a little *Polygonum* remaining; erosion evident.

The quality of the waters had also changed drastically. The pH of the lake water 30 miles from the smelter was 6 to 7 but had been reduced to 3 within 5 miles of the plant. Also, the sulfate content of the waters had greatly increased. An inorganic nutrient loss from the system was demonstrated by a significant increase in calcium in the surrounding lake waters.

Air pollution has also been viewed as a stress factor to ecosystems (Auerbach 1981; Smith 1981; Ulrich 1983). Depending upon the amount and severity of air pollution exposure, an ecosystem has various tolerance levels or thresholds. The characteristics of the ecosystem at these various tolerance levels are different. Smith (1981) has applied this concept in describing the responses of forest to air pollution. He divides the interaction of air pollutants and forest ecosystems into three classes (table 5). Under low dose conditions (Class I relationships), the vegetation and soils act as important sinks for air pollutants. In Class I relationships the impact of air emissions may be undetectable or may actually stimulate growth. At intermediate dose levels (Class II relationships), individual tree species or individual members of a given species may be subtly and adversely affected by nutrient stress, impaired metabolism, predisposition to stress from insects or pathogens, or direct disease inductions, all related to the presence of air pollution. Reduced productivity or biomass and alterations in species composition or community structure may also be observed. At high exposure (Class III relationships), acute morbidity or mortality may be observed in specific tree species. Gross simplification of the ecosystem; impaired energy flow and biogeochemical cycling; and changes in hydrology, erosion, and microclimatic alteration, as well as impacts to associated ecosystems, may occur.

Ulrich (1983) has applied the stress concept to the effects of air pollution on soil ecosystems in Europe. His theory is based on the dynamics of the ion cycle within ecosystems. In a steady state, ion uptake and mineralization balance each other. Because ion uptake and mineralization do not always occur at the same place and at the same rate, this buffering capacity (H^+/OH^- ions) determines the resiliency of the ecosystem. Air pollution can destabilize the balanced ion cycle. Ulrich identifies two stability phases: stable with high resilience and stable with low resilience. Several destabilization phases are identified: humus disintegration, buildup of the decomposer refuge, and podzolization. He concludes that all forest ecosystems in central Europe have transferred to one of the destabilization phases.

The U.S. Fish and Wildlife Service has published a series of reports summarizing the effects of air pollution, including acid rain, on fish, wildlife, and their habitats (Air Pollution and Acid Rain, FWS/OBS 80/40 series; for example, Peterson and Adler 1982). These reports are divided into reviews of major habitat types including forest, grasslands, deserts and steppes, arctic tundra and alpine meadows, rivers and streams, lakes, and critical habitats for threatened and endangered species. These reviews point out the diversity of responses by the various ecosystem types. In coastal sage-scrub ecosystems, for example, chronic exposure to photochemical oxidants is reported to cause a decrease in total foliar cover, a decreased number of plant species, and an increased number of dominant species. Effects on plant species composition are reported in oak-grassland and aspen-conifer ecosystems. Particulate pollutants are reported not only to affect species composition but also to affect other ecosystem characteristics causing changes in soil microbial activity, nutrient cycling, and the integrity of food chains in forest ecosystems. Aquatic ecosystems also have been impacted by decreased decomposition and nutrient cycling, altered primary and secondary productivity, and altered trophic levels and competitive relationships. Direct effects to fish and wildlife ranging from biomagnification to increased morbidity and mortality have been reported. Acidifying pollutants have been identified as causing similar effects to both forest and lake ecosystems. Gorham and others (1984) have recently suggested that peatland ecosystems are also vulnerable to atmospheric deposition.

An objective of many of the whole ecosystem studies is to develop a model either to describe or predict ecosystem effects (Miller and Elderman 1977; Tetra Tech, Inc. 1984). Shugart and others (1980) and Kercher and others (1981) discussed the utility of various models for evaluating stress to forest ecosystems from air pollution. Other examples of available models include a forest succession model (SILVA) for the mixed conifer forest of the Sierra Nevada of California that simulates the effects of SO_2 and fire on forest dynamics (Kercher and Axelrod 1984). Klein (1984) has developed a model to evaluate the effects of acid rain on biomass accumulation, litter, and nutrient pools, and Luxmoore (1980) has created a model for deciduous forest that links water, carbon, and chemical dynamics in a soil-plant-litter system. A major shortcoming of these models to date is that they have little application in the regulatory arena. They are not developed to predict effects at various air quality increments over a baseline condition or effects over short periods, for example 10 years.

Much effort has also been devoted to modeling the effects of acid deposition on surface water systems. A variety of models exist (for instance, Henriksen's predictor nomograph, the Almer-Dicksson relationship, and the Thompson cation denudation rate model), but this field of modeling is still considered developmental in its application to North America (Galloway and others 1984). These models are predictive and useful in determining the effects of additional acidification on soil and aquatic systems.

Reported Effects on Ecosystem Components

Research has traditionally focused on species or populations and only recently on ecosystem level studies (Sheehan and others 1984). Therefore, a major share of the present information on air quality-related values deals with ecosystem components. Drawing on these studies has resulted in a better understanding of which parts of the ecosystem structure and function are most sensitive to air quality degradation and which components may provide the most qualitative and quantitative measures of change.

Effects on Soils.—There is a close relationship between vegetation and soils, and much of the literature on the effects of air pollution discusses both together (Little and Martin 1972; Freedman and Hutchinson 1980). More singular attention has been given to soils in regard to the effects of air pollution on nutrient cycling (Johnson and others 1984) and plant productivity (Jones and others 1979). A number of reviews have summarized known or suspected effects to soils by reviewing both soil and soil-vegetation effects literature (Ulrich and Pankrath 1983; McFee and others 1984).

Soils are receptors of air pollutants. They can act as sinks and accumulate pollutants, or they can alter the chemical nature or reactivity of pollutants. Soils can act as pathways of transport for pollutants to other ecosystem components such as vegetation or animals or to other ecosystems such as lakes and streams (fig. 1). A recent review concludes that natural soil processes can contribute to an increase in H^+ ion concentration in some forest watershed surface waters (Lefohn and Klock 1985). Air pollutants can enter soil directly through deposition (wet or dry) or indirectly through leaching or washing of pollutants from vegetation and by decomposition of contaminated vegetation. Most studies on the effects of air pollutants have involved forest soils (Ulrich and Pankrath 1983; McFee and others 1984).

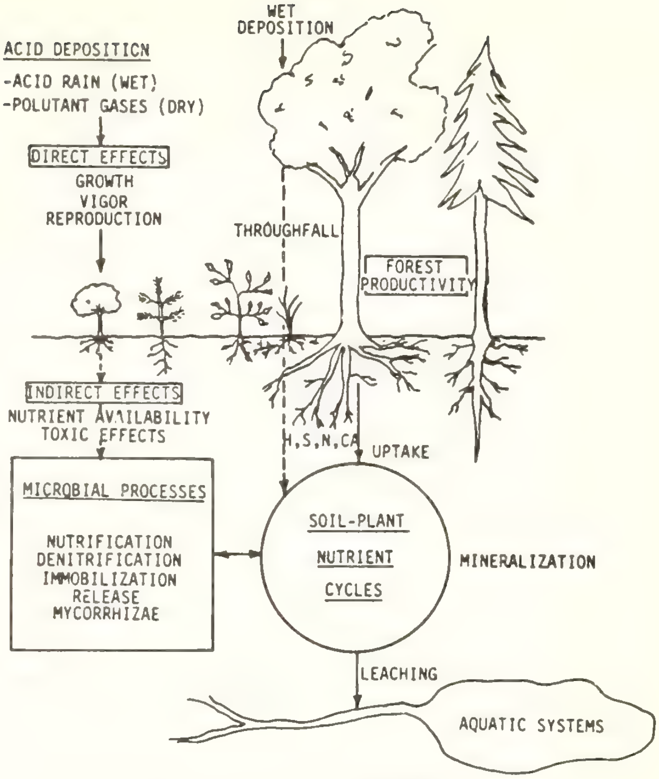


Figure 1.—Key components and processes to be considered in evaluating effects of acidic deposition on forested ecosystems (from Altshuller and Linthurst 1984).

Generalizations about the effects of air pollution on soils are dependent upon the type of soils and the particular pollutant (Cowling and Linthurst 1981). Some soils, such as clays and peats, have the capacity to absorb certain amounts of elements, thus mitigating their effects. In other soils, such as sands, the elements are more available for uptake and transport. Trace metal depostion on soils can have long-term, adverse effects as found at Copperhill, TN, and Sudbury, ON, Canada. Enrichment of soils and zones of concentration of SO_4, NO_3, trace metals, and other pollutants are often observed in soils downwind of point sources (Hutchinson and Whitby 1974; Hogan and Wotton 1984).

The effects of sulfur and other acidic deposition on soils are well summarized (Ulrich and Pankrath 1983; McFee and others 1984). Acid deposition may cause acidification of soils and associated ecosystems or contribute to natural acidification rates. Soil acidification is affected by and controlled by underlying bedrock, waterflow characteristics, and type of plant community. In areas exposed to acid deposition most soils that are easily acidified are already acid. Other soils that are likely to become acidified are limited. Agricultural soils that are amended do not appear to be affected by acid deposition. Assessing the effects of acid deposition on forest nutrient status involves quantifying the inputs and changes in availability of sulfur, nitrogen, and cations on specific sites as well as effects on microorganisms. The most likely damage to forest productivity may result from aluminum toxicity.

Acid deposition has greatly increased the rate of soil acidification in Europe, especially central Europe. Soil acidification can occur directly from dry or wet deposition or indirectly from conversion (oxidation) of SO_2 to SO_4 in vegetation or particulates washed from vegetation.

A number of effects have been observed in soils including:

- less exchange base cations,
- slower decomposition rates,
- reduced buffering capacity,
- leaching of nutrient cations,
- formation of aluminum ions and their entering into solution,
- decreased penetration of roots to lower soil horizions,
- decreased abundance and diversity of soil organisms with depth, and
- decreased plant productivity due to reduced nutrient availability.

In nutrient-poor soils the addition of sulfur and nitrogen has been found to have a positive effect, if any, on plant productivity. Nitrogen-limited soils are common; therefore, acid inputs are generally felt to be beneficial. Because of the much more limited sulfur-deficient soils, the beneficial effects of sulfuric acid are minimal. The increased mobility of aluminum in naturally acid soils is the most significant effect of acid deposition on soils because this affects processes in both the terrestrial and aquatic ecosystems (McFee and others 1984).

Effects on Vegetation.—Effects of air pollution on vegetation have been the subject of both historical and present-day investigations (Mudd and Kozlowski 1975; Heck and Brandt 1977; Lefohn and Ormrod 1984). The earliest vegetation effects were related to sulfur dioxide from point sources. A number of cases of severe damage to ecological systems from a variety of pollutants have been reported (table 6). More recently, attention has been

Table 6.—Examples of severe ecological damage in North America from air pollution (modified from Smith 1981)

Location	Source (pollutant)	Severely injured or killed species	
Redding, CA	Smelter (SO_2, metals)	Pine, oak	*Pinus* spp., *Quercus* spp.
Anaconda, MT	Smelter (SO_2F)	Douglas-fir, lodgepole pine	*Pseudotsuga menziesii*, *Pinus contorta*
Missoula, MT	Pulp mill (SO_2) (SO_2)	Ponderosa pine, Douglas-fir	*Pinus ponderosa*, *Pseudotsuga menziesii*
Superior, AZ	Smelter (SO_2, metals)	Paloverde	*Cercidium* spp.
Jackson, MS	Nuclear electric generating facility tower (SO_4^{2-})	Southern red oak, eastern white pine, sassafras, white ash	*Quercus falcata*, *Pinus strobus*, *Sassafras albidum*, *Fraxinus americana*
Colstrip, MT	Electric generating complex (SO_2)	Ponderosa pine	*Pinus ponderosa*
Copper Basin, TN	Smelter (SO_2, metals)	Pine, oak, hickory	*Pinus* spp., *Quercus* spp., *Carya* spp.
Columbia Falls, MT	Smelter (F^-)	Ponderosa pine, lodgepole pine	*Pinus ponderosa*, *Pinus contorta*
Trail, BC, Canada	Smelter (SO_2)	Ponderosa pine, Douglas-fir, western larch, lodgepole pine	*Pinus ponderosa*, *Pseudotsuga menziesii*, *Larix occidentalis*, *Pinus contorta*
Anyox, BC, Canada	Smelter (SO_2)	Western redcedar, western hemlock, Pacific silver fir, Sitka spruce	*Thuja plicata*, *Tsuga heterophylla*, *Abies amabilis*, *Picea sitchensis*
Yellowknife, NT, Canada	Smelter (SO_2, As)	Black spruce, white spruce, paper birch, poplar, willow	*Picea mariana*, *Picea glauca*, *Betula papyrifera*, *Populus* spp., *Salix* spp.
Sudbury, ON, Canada	Smelter (SO_2, metals)	Pine	*Pinus* spp.
Wawa, ON, Canada	Smelter (SO_2)	Black spruce, white spruce, fir, pine	*Picea mariana*, *Picea glauca*, *Abies* spp., *Pinus* spp.

given to the effects of acid precipitation on forest and other vegetation types (Johnson and others 1984; Postel 1984). The eastern half of the United States is a geographical area of major concern for the effects of air pollution on forest productivity (McLaughlin 1985). The forests of the area have been identified as being stressed by ozone, SO_2, and acid rain (fig. 2). Comparable concern exists in coastal California and southern California, which have already been impacted by photochemical oxidants (Miller and Elderman 1977).

Armentano and Loucks (1983), evaluating air pollution threats to national parks of the Great Lakes region, concluded that a number of parks in southern parts of the region (for example, Indiana Dunes National Lakeshore) have pollutant concentrations above the thresholds known to cause ecological effects in plants. Parks in the Great Lakes region located at great distance from primary emission sources are considered to be actually or potentially threatened by air pollution (table 7). The National Park Service has recently developed an air pollution-ecological sensitivity rating for its parks and a number of parks (approximately 20) have been found to exhibit the criteria for ecological damage (Bennett and others, this proceedings).

The effects of air pollutants on vegetation have primarily been discussed as effects to individual plants. These effects have been grouped as visible or subtle effects (Heck and Brandt 1977); acute, chronic, and hidden injury (Mudd and Kozlowski 1975); damage causing economic loss; and acute and chronic injury related to foliar and other effects (Applied Science Associates, Inc. 1978). Until recently most attention has been given to investigating the effects of a single pollutant, although in field conditions combinations or mixtures of pollutants are often the cause of damage (Lefohn and Ormrod 1984). Pollutants can affect every stage of plant development and reproduction. Besides effects on photosynthesis and respiration, pollen viability, flower and fruit abscission and set, fruit and seed development, viability, and survival can be affected (Treshow 1984).

Acute injury refers to cell death and may involve a part of a leaf or a whole leaf. Plasmolysis of the cells occurs with a subsequent collapse of the tissue. Adjacent segments of the leaf may be affected. The affected areas dry out, giving a necrotic pattern which tends to be characteristic of a given pollutant. Acute symptoms are associated with short-term exposures (hours) to varying concentrations and conditions. These symptoms usually appear within 24 hours.

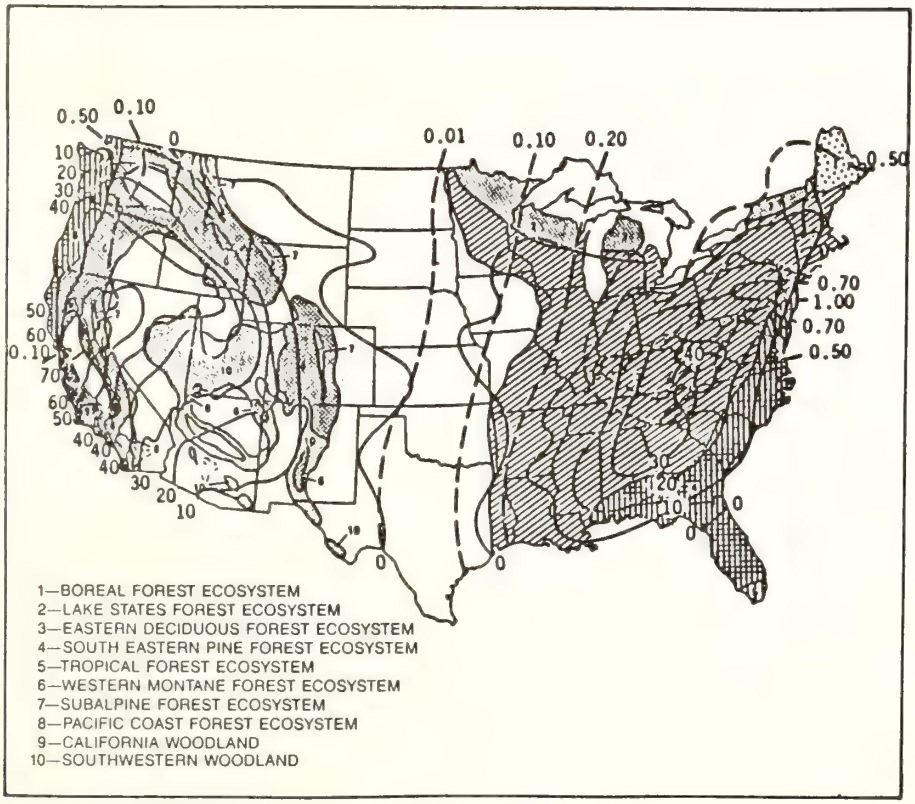

0.50
0.10
0
10
20
30
40
0.01
0.10
0.20
0.50
0.70
1.00
0.70
0.50
50
60
0.10
70
60
50
40
40
40
30
20
10
0
0
0
1—BOREAL FOREST ECOSYSTEM
2—LAKE STATES FOREST ECOSYSTEM
3—EASTERN DECIDUOUS FOREST ECOSYSTEM
4—SOUTH EASTERN PINE FOREST ECOSYSTEM
5—TROPICAL FOREST ECOSYSTEM
6—WESTERN MONTANE FOREST ECOSYSTEM
7—SUBALPINE FOREST ECOSYSTEM
8—PACIFIC COAST FOREST ECOSYSTEM
9—CALIFORNIA WOODLAND
10—SOUTHWESTERN WOODLAND

Figure 2.—Distribution of frequency isopleths for total number of forecast days with high meteorological potential for air pollution over a 5-year period. Isopleths are shown in relation to major forest types of the United States and in relation to mean annual hydrogen ion (kg/ha/yr) deposition in precipitation (from Altshuller and Linthurst 1984).

Table 7.—Actual and potential air pollution-induced threats to Great Lakes national parks and other Federal lands (modified from Armentano and Loucks 1983)

		Sources of threat			
Site	Major natural resources	SO_2 vegetation effects	O_3 vegetation effects	Visibility reduction	Acid deposition aquatic effects
1. Voyageurs National Park	Forest, lakes, stream		+	+	+
2. Grand Portage National Monument	Forest, streams, vistas		+	+	+
3. Isle Royale National Park	Forests, wildlife, streams, vistas		+	+	+
4. Apostle Isle National Lakeshore	Forests, shorelines, vistas	+		+	+
5. St. Croix National Scenic Riverway	Forests, streams, gorges, wildlife		+	+	+
6. Pictured Rocks National Lakeshore	Forests, beach outcrops, vistas		+	+	+
7. Sleeping Bear Dunes National Lakeshore	Beaches, vegetation, vistas		+	+ +	
8. Indiana Dunes National Lakeshore	Beaches, vegetation, wildlife	+ +	+ +	+ +	
9. Perry's Victory National Monument	Historical values, vistas			+ +	
10. Cuyahoga Valley National Recreational Area	Vegetation, topography, vistas	+ +	+ +	+ +	

+ = significant potential for future effects in the next two decades unless major reductions in pollutant loadings occur.

+ + = resources alterations are probably occurring now for specific pollutants indicated.

Chronic injury may be mild or severe and may also lead to cell death when cellular activity is disrupted. Chlorosis, the loss or reduction of green plant pigment, and chlorophyll or other color pigment changes may result. A second chronic effect is reduction in growth. This may be observed with or without visible foliar injury (Mudd and Kozlowski 1975). Chronic injury symptoms are not generally characteristic of a given pollutant and are more likely associated with long-term or intermittent exposures to various concentrations of pollutants (Heck and Brandt 1977). If representative of other pollutants, long-term, low-level exposure may cause growth reduction without manifesting visible injury.

Leaves are the primary focus for describing injury from air pollution. This is not to say that other plant organs, such as flowers, fruits, seeds, roots, and stems, are not sensitive or do not show injury. In general, these organs are either not directly exposed to air pollutants or their exposure is of shorter duration. Fluoride, for example, is damaging to gladiolus flowers and leaves. Injury to leaves, resulting in growth effects, may be manifested in other organs that may be used to detect effects (Applied Science Associates, Inc. 1978). A common example of this is tree ring analysis of stems to infer historical air pollution effects (fig. 3).

Besides the type of pollutant, its concentration, and duration of exposure, many environmental factors will influence a plant's response to air pollution. These include climatic factors—light, temperature, relative humidity, and soil nutrition. These factors and the seasons associated with growth can increase the sensitivity of plants to air pollution (Mudd and Kozlowski 1975).

Besides direct injury, other aspects of air pollution effects on vegetation need to be considered. Plants can accumulate pollutants and such accumulations, in addition to being directly injurious, can be harmful to animals that eat such tissues for food. Such a problem has been well documented for hydrogen fluoride and certain airborne particulates such as lead, cadmium, and arsenic (Carlson and Dewey 1971; Newman 1980; Newman and Schreiber 1985). Plants can accumulate these pollutants in their tissues or on their surfaces.

As mentioned in the beginning of this section, emission sources often release multiple pollutants that affect vegetation (Runeckles 1984). Only recently has this condition been given national attention (Lefohn and Ormrod 1984). Because of existing Federal standards, research priority is currently focused on the co-occurrence effects of ozone, nitrogen dioxide, and sulfur dioxide mixtures in air. However, any combination of pollutants, such as fluoride and

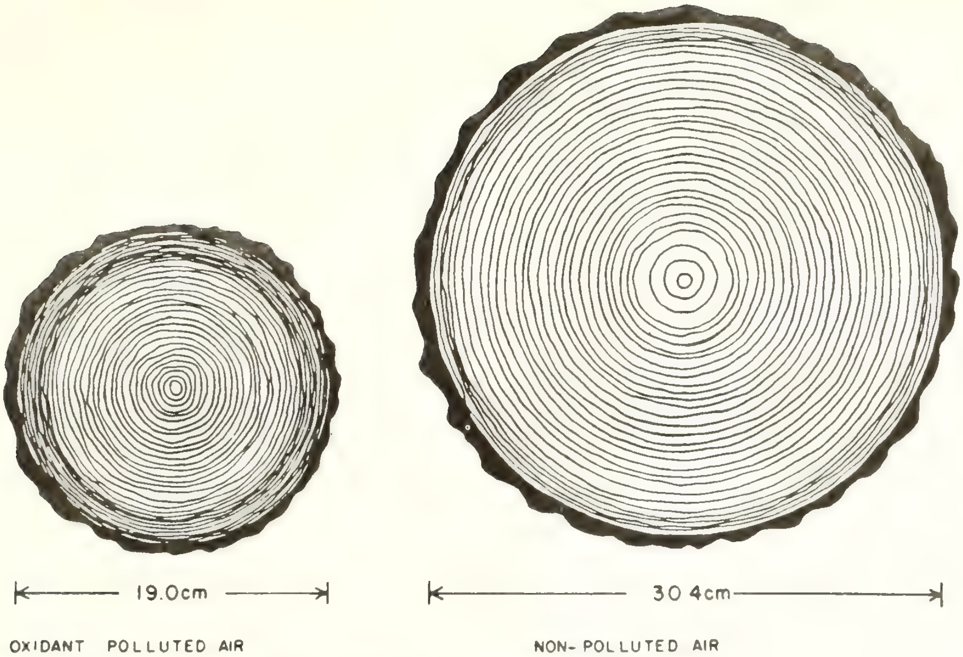


Figure 3.—Calculated average cross-section of two 30-year-old ponderosa pines at breast height grown in polluted air (left) and in nonpolluted air (right) based on radial growth samples from 1941 to 1971 and 1910 to 1940 (from Miller and Elderman 1977).

sulfur dioxide, may occur. There is the possibility that, because of synergistic effects, observed visible injury will total more than the sum of visible injury exhibited by each pollutant alone. Either an antagonistic effect or no effect is also possible. The threshold of injury is important. When pollutant concentrations are below or at their individual thresholds for visible injury, synergistic effects are often observed. Antagonistic interactions may be observed at relatively high concentrations. Insufficient experimental studies have been conducted, however, to develop diagnostic symptoms as have been described for single pollutant effects. In some mixtures, injury symptoms of one of the pollutants may be apparent while with other mixtures the symptoms may differ from those of any single pollutant in the mixture. From a wilderness protection point of view, the consideration of co-occurrence of air pollutants from a combination of nearby emission sources and from regionally derived pollutants may be critical.

Besides the direct injury to vegetation, air pollutants can create conditions which enhance other stresses on vegetation. Pollutant-plant pathogen interactions have been well documented (Heagle 1973), as have interactions between air pollutants and plant parasites. For example, in southern California considerable damage to ponderosa pine in the San Bernardino National Forest was attributed to the interaction of photochemical oxidants and western pine beetle (*Dendroctonus brevicomis*) populations (Miller and Elderman 1977). Such conditions are likely to occur in wildernesses where indigenous insects may be aided by air pollution. Air pollutants may either weaken the resistance of plant species to pest infestation, or if significant defoliation occurs because of plant pests, this may allow air pollutants to penetrate farther into the vegetation causing additional injury and further increasing susceptibility to other stresses (fig. 4). Similar interactions are suspected to occur with acid deposition (fig. 5).

The Critical Assessment Review Papers (Johnson and others 1984) draw a number of conclusions regarding the effects of acid and gaseous deposition on vegetation:

1. Ozone is the most important gaseous pollutant affecting plant life distant from industrial and urban precursor sources.
2. Direct effects, including foliar injury and reduction in growth and yield, have been recorded in forest ecosystems.
3. The effect of acid deposition on nutrient cycling and subsequent effects to plant growth and yield are important if the rate of leaching exceeds the rate of nutrient uptake.
4. At present, no direct evidence exists that acid deposition limits forest growth in either North America or Europe; however, evidence from annual rings indicates that tree growth rates are lower in coniferous forests where the rainfall acidity is high or the annual average pH of precipitation is low (pH <4.3).

The major research needs relating to air quality effects on wilderness vegetation are additional cause-and-effect relationship studies in field conditions. Studies are needed

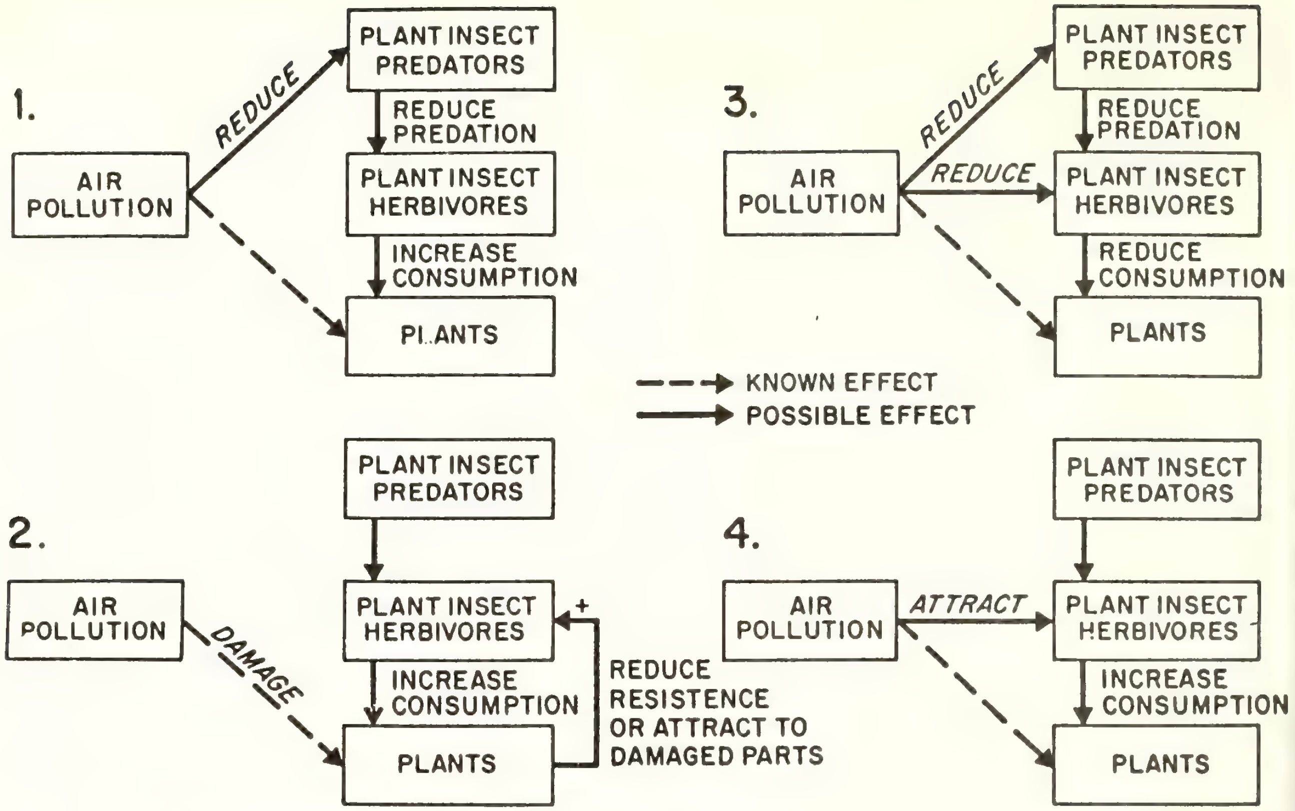

1.
AIR POLLUTION
REDUCE
PLANT INSECT PREDATORS
REDUCE PREDATION
PLANT INSECT HERBIVORES
INCREASE CONSUMPTION
PLANTS
3.
AIR POLLUTION
REDUCE
REDUCE
PLANT INSECT PREDATORS
REDUCE PREDATION
PLANT INSECT HERBIVORES
REDUCE CONSUMPTION
PLANTS
KNOWN EFFECT
POSSIBLE EFFECT
2.
AIR POLLUTION
DAMAGE
PLANT INSECT PREDATORS
PLANT INSECT HERBIVORES
+
INCREASE CONSUMPTION
PLANTS
REDUCE RESISTENCE OR ATTRACT TO DAMAGED PARTS
4.
AIR POLLUTION
ATTRACT
PLANT INSECT PREDATORS
PLANT INSECT HERBIVORES
INCREASE CONSUMPTION
PLANTS

Figure 4.—Four possible mechanisms of air pollution impacts on insect-plant relations (from Newman 1975).

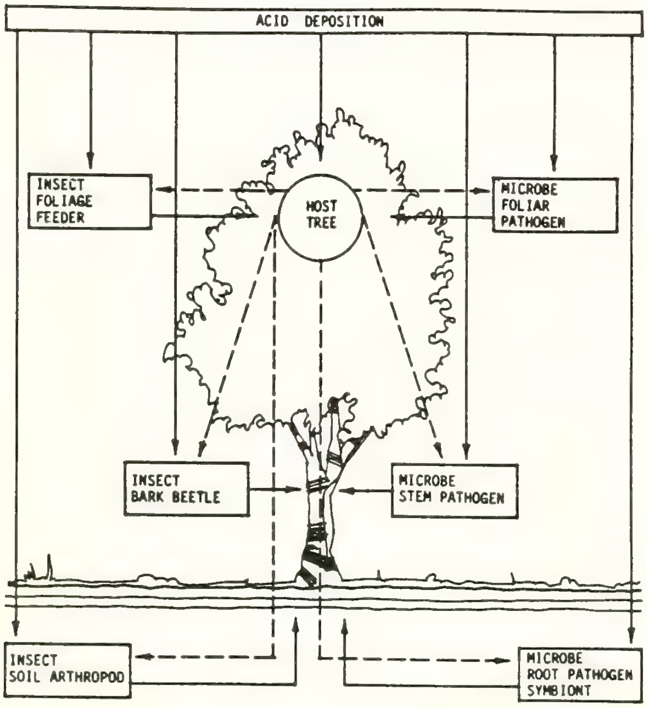

ACID DEPOSITION
INSECT FOLIAGE FEEDER
HOST TREE
MICROBE FOLIAR PATHOGEN
INSECT BARK BEETLE
MICROBE STEM PATHOGEN
INSECT SOIL ARTHROPOD
MICROBE ROOT PATHOGEN SYMBIONT

Figure 5.—Acid deposition may influence insects, pathogens, and symbionts associated with forest trees by direct influence (solid arrows) or indirect influence via host alteration (dashed arrows) (from Altshuller and Linthurst 1984).

to show whether observed declines and damage to vegetation at a regional scale are due to air pollution. In addition, the separation of multistress factors and determination of the contribution of air pollution to observed changes in vegetation are also needed (Bennett 1985a).

Effects on Water.—Water is a sink for many pollutants. The sources of these pollutants range from agricultural runoff to industrial waste effluents. Where these multiple sources of contamination exist, pinpointing the contribution of air pollution and correlating the effects on aquatic organisms are difficult. Aquatic ecosystems in close proximity to a major emission source have been shown to be affected (Lefohn and Brocksen 1984; Nriagu 1984). The major atmospheric influences from emission sources are acid deposition and trace metals. These influences can be from direct deposition on the water body or from input through the watershed.

Considerable effort has been devoted to characterizing the sensitivity of aquatic ecosystems to water quality change caused by acid deposition (Hendrey and others 1980; Lippincott and others 1982; Loucks and others 1984; Brakke and others 1985). For rivers and streams, high order (<3) and soft water systems are considered to be the most sensitive. These systems are characterized by cold (<68 °F), shallow waters, with turbulent flow and rubble and gravel substrates. There is usually a high gradient and extensive shade and cover. The waters contain coarse particulate organic matter and have low alkalinity (Potter and others 1982). Larger rivers and streams at lower elevations or in more developed areas are likely to be less affected because of greater buffering capacity, dilution, and inputs from other anthropogenic sources (Potter and Alder 1982; Haines and Akielaszek 1984).

Lake sensitivity is well studied (Tetra Tech, Inc. 1984). The less the ability of the watershed to neutralize the acid deposition, the more sensitive the lakes are to acidification. Sensitive lakes are those with low total alkalinity, neutral or below neutral pH, low hardness, low conductivity, and generally low productivity.

Geographical areas where acid deposition is recognized as affecting or potentially affecting aquatic systems include New England and the Adirondack region; the Middle Atlantic and Appalachian area plus parts of the Southeast, including Florida; portions of the upper Midwest; and some higher elevation areas of the Rocky Mountains, Pacific Northwest, and California. The current National Surface Water Survey is an attempt to further define these areas of sensitivity and to establish long-term monitoring for trend analysis (Brakke and others 1985). Recent attention has focused particularly on the situation in the West (Lippincott and others 1982; Gibson and others 1983; Roth and others 1985). Because of the number of wildernesses in the West, this potential threat to water quality via atmospheric transport should be carefully monitored. The Environmental Protection Agency has recently summarized what is known or suspected about the effects of acid deposition on aquatic systems (Wilhour 1985). These include:

- Episodic acidification events (storms and snowmelt) may be more important than long-term chronic acidification in some aquatic ecosystems.
- Bedrock, soils, hydrological characteristics, vegetation, land use, and climate can all affect "susceptibility."
- Alkalinity is the best single measure of sensitivity.
- Some regions of the country currently receive elevated concentrations of trace elements in the deposition.

Water quality changes resulting from acid deposition include reduction in pH of the water and the form and availability of metals. The degree of pH reduction is related to the amount of acid material deposited directly into the water body or deposited in the watershed and flowing into the system from surface or ground water flow. The buffering capacity of the terrestrial and aquatic systems moderates the chemical response. The mobilization of aluminum from terrestrial systems is a major factor because its availability and that of other trace elements in water increases with acidic conditions (Potter and others 1982; Altshuller and Linthurst 1984). The effects of these water quality changes on organisms are discussed in the next section.

Effects on Fish and Wildlife.—The impact of airborne pollutants on fish and wildlife resources is usually more difficult to discern than for other ecosystem components. The effects are more likely subtle or indirect, such as contaminated vegetation consumed by terrestrial wildlife or bioaccumulation of metals in the aquatic food chain. Recent reviews have summarized much of this information (Drablos and Tollan 1980; Newman 1980; Haines 1981; Haines and Johnson 1982; Fischer 1983, 1984; Altshuller and Linthurst 1984; Mayer and others 1984; Schreiber and Fischer in press; Schreiber and Villella 1985). Our incomplete understanding of responses and consequences from acute or chronic events of degraded air quality for both terrestrial and aquatic species at the individual or population level is evident when impact assessment is required

Effects of airborne pollutants on fish and wildlife resources have been recorded for a number of years, but both the frequency and diversity of pollutants and the number of species impacted have increased in recent years (Newman 1975, 1980; Haines 1981; Newman and Schreiber 1985). The effects have been physiological, toxicological, and ecological (Dvorak and Lewis 1978; Fromm 1980; Newman 1980). In both terrestrial and aquatic ecosystems the impacts tend to follow pathways that involve: (a) metal accumulation and toxicity, (b) alterations in nutrient and energy cycling, (c) changes in food resources, and (d) loss or degradation of habitat (Fritz 1980; Clark and Fischer 1981; Baker and others 1984; Schreiber and Fischer in press; Schreiber and Villella 1985).

For aquatic species that depend on the water environment for some part of their life cycle, the effects are often the most direct and perhaps the most dramatic. Air pollutants may interact with the aquatic media either directly (dry and wet deposition) or indirectly after interception and alteration by the terrestrial environment (soils, vegetation). As indicated in the previous section, the result of this interaction may add materials which cause damage to aquatic biota and change ecosystem processes. For example, low-pH precipitation caused by acidifying pollutants can leach aluminum from the soils, creating runoff that contains aluminum levels toxic to aquatic organisms. Acid precipitation causes loss of buffering capacity in low-alkalinity waters, ultimately reducing species diversity and productivity and simplifying the ecosystem (Drablos and Tollan 1980; Haines 1981; NRCC 1981; Swedish Ministry of Agriculture 1982; Baker and others 1984). Food availability and quality can decrease as the trophic dynamics of the aquatic system are changed. Aquatic taxa demonstrate wide ranges of pH tolerance (tables 8 and 9). When acid-sensitive species are reduced or eliminated, the competitive advantage shifts to more acid-tolerant organisms.

Direct impacts of low pH to fish species may include acute mortality, osmoregulatory failure and other physiological stress; predisposition to disease; and reproductive stress, including endocrine imbalances, curtailed spawning, and genetic damage, leading to recruitment failure (Baker and others 1984). The combination of low pH and aluminum that may occur in spring runoff can induce excess mucus secretion in the gills of fish, causing death by asphyxiation. Episodic depressions in pH are particularly threatening to eggs and the early life stages of fish when there is generally lower acid tolerance (NRCC 1981). Mobilization of metals by acid precipitation can also lead to bioaccumulation, affecting fish and other top predators in the aquatic food chain. For example, elevated levels of mercury have been detected in fish from acid lakes (Wiener 1983) although the consequences to the species or its predators, including piscivorous birds and mammals, are unknown.

Table 8.—Median minimum pH tolerances of different aquatic taxa (adapted from Eilers and others 1984)

Taxonomic group	Median pH tolerance
Algae	
Bacillariophycea (diatoms)	6.0
Desmidiaceae (desmids)	5.25
Chlorophyta (green algae)	4.6
Cyanophyta (blue-green algae)	4.5
Euglenophyta (flagellates)	3.1
Insects	
Odonata (dragonflies)	6.4
Trichoptera (caddisflies)	6.3
Ephemeroptera (mayflies)	6.0
Hemiptera (bugs)	6.0
Diptera (true flies)	5.6
Coleoptera (beetles)	5.5
Plecoptera (stoneflies)	5.2
Miscellaneous groups	
Pelecypoda (bivalves)	6.65
Gastropoda (snails)	6.6
Hirudinea (leeches)	6.55
Porifera (sponges)	5.5
Crustacea (crustaceans)	5.2
Teleostei (fish)	4.9
Anura (frogs)	4.1

Table 9.—Approximate pH at which reproductive failure has been observed in fish (compiled from Baker and others 1984; Haines and Johnson 1982)

Species	pH range
Smallmouth bass (*Micropterus dolomieui*) Walleye (*Stizostedion vitreum vitreum*) Burbot (*Lota lota*)	6.0+ to 5.5
Atlantic salmon (*Salmo salar*) Brown trout (*Salmo trutta*) Lake trout (*Salvelinus namaycush*) Rainbow trout (*Salmo gairdneri*) Trout-perch (*Percopsis omiscomaycus*)	5.5 to 5.0
Brook trout (*Salvelinus fontinalis*) White sucker (*Catostomus commersoni*) Rock bass (*Ambloplites rupestris*)	5.0 to 4.7
Lake herring (*Coregonus artedii*) Lake chub (*Couesius plumbeus*) Yellow perch (*Perca flavescens*)	4.7 to 4.5

Amphibians and waterfowl are also candidates for impacts from airborne pollutants that enter the aquatic ecosystem. Amphibians are vulnerable because their prime breeding sites are often small, temporary ponds formed from snowmelt and spring rains (Clark and Fischer 1981; Tome and Pough 1982; Pierce 1985). The reported effects on amphibians from pH depressions include:

- embryo deaths and deformities,
- decreased egg masses,
- reduced densities,
- increased percentage of dead or molded egg masses,
- osmoregulatory failure,
- delayed development,
- abnormalities, and
- decreased sperm motility (U.S. EPA 1983).

Although the role of amphibians in nutrient flow and their contribution to the food chain are often overlooked (Pierce 1985), their reduction or loss would be expected to cause major changes in ecosystems structure and function. They may also provide an early indication of pollutant stress (Perley and Fischer 1983; Newman and Schreiber 1984) and thus may be particularly useful for monitoring in wildernesses.

Present information on the effects of air pollutants on waterfowl is inconclusive. It is likely that piscivorous species such as loons (*Gavia* spp.), herons, and mergansers (*Mergus* spp.) will be unable to rear young in areas where acidification has reduced fish populations. Other waterfowl species, such as the mallard (*Anas platyrhynchos*) and common goldeneye (*Bucephala clangula*), may benefit to some degree from the increased availability of aquatic invertebrates resulting from reduced competition in fishless lakes (Eriksson 1984; Baker and others 1984).

For fish-eating birds, such as the osprey (*Pandion haliaetus*), which search for fish while flying or hovering over the water surface, any benefit of increased water transparency in acid lakes is likely offset by the reduction in fish populations (Eriksson 1984, 1985). Birds at the top of the aquatic food chain may also risk greater exposure to heavy metals that are mobilized by the acidic conditions (Nyholm 1981), although the question is still debatable.

Terrestrial wildlife are potentially affected by air pollution through inhalation of airborne gases and particulates, by drinking water or consuming food that has been affected by these pollutants, or indirectly by the influence of these materials on their habitat (Newman 1980; Schreiber and Fischer in press; Schreiber and Villella 1985). A number of incidences demonstrating impacts have been recorded historically (Newman 1980) and in recent years (tables 10 and 11).

Terrestrial species are likely to show bioaccumulation of metals because of their position in the food chain. Some metals, such as mercury, cadmium, and lead, may enter the terrestrial ecosystem directly through atmospheric transport, whereas others, such as aluminum, may enter indirectly through the acidification process. Once mobilized, these trace elements may be incorporated in the vegetation and subsequently ingested by wildlife. This evidence has been summarized (Newman and Schreiber 1985; Schreiber and Fischer in press; Schreiber and Villella 1985), but impacts to populations remain inconclusive for the most part. In wilderness areas the general

Table 10.—Examples of incidents involving the adverse effects of airborne pollutants and birds (modified from Newman 1980; Newman and Schreiber 1985)

Species	Pollutant	Effect
Small birds	Hydrogen sulfide	Death
House martins (*Delichon urbica*), swifts	Particulates	Reduced populations
House sparrows (*Passer domesticus*)	Fluoride	Biological concentrations
House sparrows	Photochemical oxidants	Respiratory lesions
Passerines	Hydrogen sulfide	Death
Sparrow (*Passer* spp.)	Cadmium	Death
Larks	General air pollution	Reduced populations
Sparrowhawks, song thrushes, owl	Cadmium	Food chain magnification
House martins	Sulfur dioxide, particulates, nitrogen oxides, fluoride	Reduced nesting
Ducks	Trace metals	Biological concentration
Owls, songbirds	Hydrogen sulfide	Death
Pigeons	Lead	Biological concentration

Table 11.—Examples of incidents involving the adverse effects of airborne pollutants and mammals (modified from Newman 1980; Newman and Schrieber 1985)

Species	Pollutant	Effect
Fallow deer (*Dama dama*)	Arsenic	Death
Red deer (*Cervus elaphus*) Roe deer (*Capreolus capreolus*) Rabbits (*Oryctolagus cuniculus*)	Arsenic	Death to 60 to 70 percent of individuals
White-tailed deer (*Odocoileus virginianus*)	Fluoride	Fluorosis
Hares (*Lepus europaeus*)	Sulfur dioxide, fly ash	Hypocalcemia and hypoproteinesis
Bighorn sheep (*Ovis canadensis*)	Oxidants	Blindness
Voles, mice, rats, and shrews	Lead, cadmium, copper	Biological concentrations
Small mammals	Oxidants	Reduced populations
Roe deer	Sulfur dioxide, particulates	Reduced antler quality
Wood mice, bank voles	Fluoride	Biological concentrations
Black-tailed deer (*Odocoileus hemionus*)	Fluoride	Browse contamination
Deer mice (*Peromyscus* spp.)	Ozone	Genetic change in sensitivity to ozone
Bats, mice	Hydrogen sulfide	Death
Foxes	Fluoride	Biological concentrations

lack of monitoring and paucity of historic and current baseline data would likely further preclude the detection of this impact.

In cases where the pollutant affects a food resource, the ramifications to both individuals and populations may be significant. For example, populations of insectivorous birds may be affected when their prey is influenced by air pollution (Newman and others 1985). Species with restricted diets, which include some of the threatened or endangered wildlife, are at particular risk in these circumstances.

Case Studies of Ecosystem Research Programs

In the past 15 to 20 years a number of large-scale, comprehensive studies have been conducted in the attempt to determine the influence of individual or combinations of airborne pollutants on various types of ecosystems (tables 12 and 13). Each study has significantly increased our understanding of the interaction of transient gases and particulate matter on terrestrial and aquatic systems. These ecosystem studies have been of several types—studies to assess an already recognized problem (for example, San Bernardino Mountains photochemical oxidant study), studies to assess potential effects of air pollution (for example, Colstrip studies), and studies to develop assessment tools for air pollution effects (for example, integrated lake-watershed acidification studies). Many of the large ecosystem studies are now concerned with acid deposition effects. Although ozone is recognized as an equally serious problem, only one ecosystem-level study on its effects has been undertaken, and funding was unavailable for its completion. These ecosystem-level studies are important for wilderness evaluations because they have demonstrated the multilevel, interactive component effects that air pollution has on natural systems.

The following case studies are representative of these types of projects and their relevance to wilderness research.

Table 12.—Major ecosystem studies on the effects of air emissions in North America (modified from Newman and Schreiber 1984)

Name of study	Ecosystem (location)	Pollutant stress
Experimental Lakes Area (ELA) watershed studies	Lakes in northern coniferous forest (Ontario)	Acid deposition
Turkey Lake Forest watershed study	Lakes in northern deciduous forest (Ontario)	Acid deposition
Dorset watershed studies	Lakes in northern forest (Ontario)	Acid deposition
Montmorency experimental forest study	Northern coniferous forest and associated lakes (Quebec)	Acid deposition
Kejimkujik calibrated catchment program	Northern coniferous forest (Nova Scotia)	Acid deposition
Integrated Lake-Watershed Acidification study (ILWAS)	Lakes in northeastern deciduous forest (New York)	Acid deposition
Kaybob gas plant study	Transition montane boreal forest (Alberta)	SO_2
Coal-fired powerplant project at Colstrip	Northern grassland (Montana)	SO_2 and particulates
San Bernardino mountain study	Mixed coniferous forest (California)	Oxidants
Whitecourt gas plant study	Mixed coniferous forest (Alberta)	SO_2
Hubbard Brook ecosystem project	Northern mixed deciduous coniferous forest (New Hampshire)	Atmospheric deposition including acid and trace elements
Walker Branch watershed study	Mixed deciduous forest (Tennessee)	Atmospheric deposition including acid and trace elements

Table 13.—Preliminary survey list of existing air pollution-ecological field studies for various locations in North America

Location	Pollutant	Organism or ecosystem component	Reference or contact
Everglades NP, FL	SO_2	Lichens	Environmental Sciences and Engineering, Inc., Florida - R. Hart
Everglades NP, FL	SO_2	Bromeliads and orchids	Oberlin College - D. Benzing
Class I area national parks	SO_2 Ozone, wet deposition	Sensitive plant species ranking	Oak Ridge National Laboratory - R. Olson
Cuyahoga Valley NRA, OH	Various air pollutants NO_x, O_3, SO_2	Eastern white pine (*Pinus strobus*)	Ohio State University - J. McClenahin
British Columbia	Ozone	Native fir species	Ministry of Environment - J. Van Barneveld
British Columbia coastal area	Acid deposition	Salmon	Fisheries and Oceans, Canada
Upper Midwest	Acid precipitation	Lakes and associated aquatic resources	USEPA Research Laboratory, Duluth, MN - G. Glass
Voyageurs NP, MN	Acid precipitation	Lakes, water quality	U.S. Geological Survey - G. Payne
Voyageurs NP, MN	Acid precipitation	Northern pike (*Esox lucius*) (spawning)	Voyageurs NP - L. Kallemeyn
Voyageurs NP, MN	Sulfur and other elements	Lichens	University of Minnesota - C. Wetmore
Voyageurs NP, MN	Acid precipitation	Lakes, water quality	University of Western Iowa - W. DeKock
Nine parks	Ozone	Hardwood trees	Michigan Technological University - D. Karnosky
Voyageurs NP, MN	Ozone	Bioindicators—variety of plant species	University of Minnesota - P. Teng
Upper Midwest including Voyageurs NP, MN	Acid precipitation	Lakes, aquatic chemistry	University of Minnesota - P. Brezonik
Shenandoah NP, VA	Lead and sulfur	Lichens	George Mason University - J. Lawrey
Joshua Tree NM, CA	Oxidants	Desert plants	University of California - P. Temple
Western Tennessee	Acid deposition	Forest soil invertebrates and small burrowing animals	Mississippi State University - R. Esher
Coastal California	Ozone and SO_2	Coastal sage scrub vegetation	NASA-Ames Research Center - W. Westman
Glen Canyon NP; Canyonlands NRA, AZ	SO_2	Vegetation	National Park Service - P. Sanchini
Everglades NP, FL	SO_2	Slash pine (*Pinus elliottii*)	National Park Service - J. Bennett
Lostwood NWR, ND	SO_2, particulates	Lichens	Fish and Wildlife Service
Glacier NP, MT	Acid deposition, particulates	Lichens	National Park Service - Glacier NP
Zion NP, UT	SO_2, particulates	Lichens	National Park Service - Sequoia NP
Craters of the Moon W, ID	Acid deposition, particulates	Unspecified biomonitors	National Park Service - Craters of the Moon
Flat Tops W, CO	Various	Lichens	Forest Service - White River National Forest
20 Eastern U.S. parks	Ozone	Common milkweed (*Asclepias* spp.)	National Park Service - Division of Air Quality
Hampton NHS, Gettysburg NMP, VA; Fredricksburg-Spotsylvania NMP, VA; Petersburg NB	Ozone	Black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), wild grape (*Vitis* spp.), sassafras (*Sassafras albidum*), tulip poplar (*Liriodendron tulipifera*), dogwood (*Cornus* spp.), milkweed, witchhazel (*Hamamelis virginiana*), eastern redbud (*Cercis canadensis*), eastern white pine (*Pinus strobus*), Austrian pine (*Pinus nigra*), foliar injury	National Park Service - Division of Air Quality

(con.)

Table 13. (Con.)

Location	Pollutant	Organism or ecosystem component	Reference or contact
Isle Royale NP, MI; Theodore Roosevelt NP, ND; Everglades NP, FL; Shenandoah NP, VA; Great Smoky Mountains NP, TN-NC	Sulfur	Lichens	National Park Service - Division of Air Quality
Shenandoah NP, VA	Lead	Lichens	National Park Service - Division of Air Quality
Great Smoky Mountains NP, TN-NC	Lead	Leaf litter	National Park Service - Division of Air Quality
Big Thicket NP, TX	Sulfur, heavy metals	Spanish moss (*Tillandsia usneoides*)	National Park Service - Division of Air Quality
Mount Rainier NP, WA	Arsenic	Subalpine fir foliage	National Park Service - Division of Air Quality
Great Smoky Mountains NP, TN-NC	Heavy metals	Red spruce (*Picea rubens*)	National Park Service - Division of Air Quality

NP = National Park; NM = National Monument; NRA = National Recreational Area; NHS = National Historical Site; NMP = National Military Park; NB = National Battlefield; NWR = National Wildlife Refuge; W = Wilderness.

Effects of Emissions From a Coal-fired Powerplant on a Northern Prairie Grassland.—

Ecosystem Type/Location/Duration:

A pristine northern plains grassland, with scattered stands of ponderosa pine; Rosebud County in southern Montana; started in 1974 and completed in 1980 (Lauenroth and Preston 1984).

Pollutant Type/Source:

Stack emissions (particularly SO_2) from two 350-megawatt coal-fired generating units; simulation experiments with a zonal air pollution system (ZAPS) for SO_2 stress.

Objectives:

To measure and predict change in a grassland ecosystem as a function of environmental variables including air pollutants.

Methods and Monitoring Techniques:

The approach was to study the field response to pollution stress by the major parts of the trophic structure of the ecosystem, including representative populations of the microorganisms, producers, and consumers. To complement these field investigations, laboratory experiments were conducted to evaluate ecosystem behavior to selected trace metals associated with emissions from coal-fired powerplants. One of the unique features was the development of a controlled zonal air pollution system (ZAPS) for field fumigation experiments. This network of perforated pipes provided exposure regimes of SO_2 that simulated short-term acute and long-term chronic fumigation events.

Major Results and Conclusions:

The Colstrip coal-fired powerplant project in Montana was a first attempt at generating methods to predict the bioenvironmental effects of air pollution before damage was sustained. The supporting field and laboratory process studies were designed to investigate the mechanisms for cause-effect relationships. The project incorporated environmental characterization of the grassland ecosystem prior to construction of the powerplant and subsequent monitoring of the key ecosystem components after operation to detect impacts from the air pollution. Initial predictions of large and obvious impacts from SO_2 exposure did not occur, and emphasis shifted toward determining appropriate indicators of impact.

In this grassland study, grasses and lichens predominated. Previous grazing and annual climate variations excluded grasses as a reliable indicator of stress, but lichen species were sensitive in detecting SO_2 levels. Research demonstrated that the increase in concentration and accumulation of sulfur by vegetation was related to level and duration of exposure, productivity and growing season, soil nutrients, and defoliation treatments. However, only at very high SO_2 treatment (1 to 2 orders of magnitude greater than current PSD standards) were there indications of direct toxic effects.

For the heterotrophs studied, total arthropod populations were not significantly affected, but some soil-water-associated organisms showed declines. Laboratory studies of grasshoppers suggested physiologically marginal individuals were adversely affected by SO_2 exposure. Palatability of exposed leaves was reduced. The pollen-nectar feeding group of arthropods showed a decline, apparently due to their SO_2 sensitivity.

Effects of Photochemical Oxidant Air Pollution on a Mixed Conifer Forest Ecosystem.—

Ecosystem Type/Location/Duration:

A western mixed-conifer mountain ecosystem; the San Bernardino Mountains of southern California; started in 1973 and completed in 1978 (Miller and Elderman 1977; Miller 1983).

Pollutant Types/Source:

Photochemical oxidants from urban sources in Los Angeles basin.

Objectives:

To determine chronic effects of photochemical oxidants on a mixed conifer ecosystem including forecasting ecological effects, evaluating consequences of pollutants in a forest ecosystem on human welfare, and evaluating the adaptability of system models to other pollutants and forest types.

Methods and Monitoring Techniques:

The study was divided into a number of ecosystem components, with teams of scientists conducting individual studies which were then integrated into a larger system model. The ecosystem components measured were the physical-chemical properties of soil, regional climatological conditions including windflow and precipitation, photochemical oxidants (monitored annually), status and health of vegetation communities, decomposition processes, and small mammal population dynamics. Eighteen study plots were set up in a gradient from high to low oxidant levels. Conceptual models were developed for the various ecosystem components including a number of submodels for forests (tree moisture, oxidant flux-canopy response, tree growth, pests, and pathogens).

Major Results and Conclusions:

This study was one of the earliest ecosystem studies that attempted to describe the effects of an air pollutant on an entire ecosystem. It documented factors affecting and contributing to the decline in ponderosa pine and Jeffrey pine (*Pinus jeffreyi*) in the San Bernardino Mountains. The effects of other natural stress factors, such as defoliating insects and root pathogens, were enhanced by photochemical oxidants. Forest areas with different topographical conditions, such as precipitation patterns, were affected differentially by oxidants. A gradient of chronic injury in ponderosa and Jeffrey pine was correlated with oxidant concentration. The deciduous California black oak (*Quercus kelloggii*) was a useful indicator of the rate of injury development. Under the worst case, it is predicted that continuous subjection of these forest stands to the combination of ozone and periodic fires would result in an irreversible conversion to a less desirable (in terms of visual appeal, merchantable commodities, and recreational opportunities) oak-brush cover.

An Integrated Lake-Watershed Acidification Study (ILWAS).—

Ecosystem Type/Location/Duration:

Three forested watersheds, located in northern hardwood-spruce-fir forest; Adirondack State Park, NY; started in 1977 and completed in 1984 (Tetra Tech, Inc. 1984).

Pollutant Type/Source:

Acid deposition from regional sources.

Objectives:

To develop a tool to assess the amount of acidification that can or has occurred as a result of atmospheric deposition.

Methods and Monitoring Techniques:

The acid-base chemistry and hydrology of three watersheds and lakes (Woods, Sagamore, Panther) were monitored and measured for 4 years. The system was divided into a number of components including atmosphere, canopy, snowpack, vegetation, soil, bogs, streams, and lakes. These data, along with related meteorological data and laboratory experimental findings, were used to develop and test a mechanistic simulation model that calculates rates of change in the acidity of surface water as a function of changing atmospheric deposition levels.

Major Results and Conclusions:

The ILWAS study was a research project designed to develop a tool for relating the amount of acid deposition to lake acidity, factoring in watershed biogeochemical processes. It was not an environmental assessment as such. The results showed that the acid-base status of lakes is determined by the interaction of many factors including soil, hydrology, vegetation, geology, climate, and atmosphere. A factor's role can vary both geographically and temporally and must be viewed in terms of the ecosystem of which it is a part. The rate at which hydrologic basins supply alkalinity to through-flowing water establishes the vulnerability of lakes to acidification. In lake ecosystems isolated from alkaline rock by impermeable soils, the alkalinity source is removed. The model developed is intended for use in assessing the vulnerability of surface water to acidification by atmospheric acids and determining effective management strategies for acidic surface waters. Studies are currently underway to test and increase the geographical utility of the model in such areas as Wisconsin, North Carolina, and California. A 4-year study, funded by the Electric Power Research Institute, was recently initiated to evaluate the role of acid deposition in producing changes in nutrient cycling. The study will be conducted at forested sites in the Northeast (Whiteface Mountain), Northwest (Cascade Mountains), and the Southeast (Smoky Mountains) (Bondietti and others 1985).

UNDERSTANDING AIR QUALITY CONDITIONS IN WILDERNESSES

In an attempt to meet the objectives of this conference, a survey was made of the Class I areas to determine the status of air quality conditions and to identify ongoing research and future ecological research needs related to air quality. This survey was conducted by contacting the Class I area personnel and asking to speak to the air quality specialist, or the manager if no specialist was known. Ninety-seven of the 158 Class I areas were contacted (appendix). Of the Class I areas contacted, 20 percent indicated that ecological effects from air pollution had been documented (table 14). A larger number (47 percent) felt that future air quality effects were likely. Over a third (37 percent) of Class I areas surveyed had been involved in a PSD permit review. A majority of the Class I areas (78 percent) were able to identify "existing air quality influences."

Several studies, including our survey, indicate that wildernesses are already affected by a decline in air quality. Federal land managers surveyed were able to identify existing and potential air quality sources influencing their Class I areas (table 15). Class I areas in the Eastern United States are perceived to be influenced more by

Table 14.—Documented ecological effects to Class I areas as reported by Federal land managers

Documented effects	FWS[1]	FS[1]	NPS[1]	All
	Number of areas			
Yes	2	5	[2]12	19
No	16	55	2	73
Unknown	1	1	0	2

[1] FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

[2] Bennett (1985b) reports over 20 NPS lands have documented effects.

Table 15.—Percentage of identified existing and future air pollution influences for Class I areas

	Eastern U.S.		Western U.S.	
Sources	**Existing**	**Future**	**Existing**	**Future**
Natural	8	12	28	11
Point	60	70	31	49
Regional	32	18	41	27

point sources than regional sources. In the West, regional sources are now considered to be major influences, but point sources are expected to be a more important future problem. Natural sources (for instance, forest fires) also affect air quality in the West and are viewed to have a continuing importance although less so in the future.

Ten national parks have been found to have extensive damage to vegetation from ozone and sulfur dioxide (Bennett 1985b). The Park Service has developed a sensitivity rating of parks to air pollution (Bennett and others, this proceedings). Although this rating was developed for setting research priorities, it is indicative of the potential vulnerability of parklands (including wildernesses) to air pollution. Armentano and Loucks (1983) evaluated 10 national parks and other Federal lands with regard to air pollution. Ozone and acid rain effects have been demonstrated in the majority of these areas. Potential effects from SO_2 and ozone are predicted in the remaining areas. Based on these and other studies it can be concluded that wildernesses in the Eastern United States are presently being affected by ozone and acid deposition and in some locations possibly by SO_2. In the Western United States ozone is a real threat, especially to wilderness areas in California. Acid deposition is presently being evaluated in a number of western regions and appears to be a potential threat to wildernesses.

Although not all Class I areas were contacted, a number of conclusions can be drawn regarding the air quality conditions of wildernesses and the Federal land manager's role and understanding in protecting them from air pollution. The Clean Air Act and its amendments of 1977 set a procedure for protection of Class I wildernesses and delegated authority to Federal land managers for this protection. After 8 years there still appears to be a large number of Class I areas for which little progress has been made in developing and collecting AQRV baseline information, as well as air quality monitoring information. Many Federal land management personnel are generally unfamiliar with air quality effects. Because of the activity of the Air Quality Division, the Park Service personnel showed a greater understanding of air quality issues affecting their areas. This understanding is also reflected in the amount of air quality research being conducted in Park Service units (Bennett 1985b). In contrast to other agencies, each Park Service Class I area had an air quality specialist, usually a member of the Resource Management staff.

Differences exist in the ecological resources of the Class I areas that different agencies manage, and these differences may affect the degree of air quality understanding. For example, the Forest Service and Park Service manage Class I areas with the greatest diversity of ecosystem types, ranging from glaciers to deserts, with forests being the most common (table 16). The Fish and Wildlife Service's Class I areas are not only fewer in number but are primarily water related (riparian and wetland ecosystems), although forests do make up a significant number of the ecosystem types. The areal extent and proximity to industrial and urban development have not been correlated at this time, but these are also considered to affect the understanding reflected in the survey. When questioned about known air pollution influence, Class I area managers most frequently mentioned urban emission sources and regional haze as the top two air quality influences to their lands (table 17). Urban and

Table 16.—Major ecosystem type of surveyed Class I areas

Ecosystem type	FWS[1]	FS[1]	NPS[1]	All
Glaciers	—	2	1	3
Alpine	—	20	4	24
Subalpine	1	21	4	26
Forest	5	47	12	64
Chaparral	2	2	—	4
Desert	—	3	2	5
Grassland	6	3	2	11
Riparian	4	6	1	11
Wetland	8	—	1	10
Other	3	—	2	5

[1] FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

Table 17.—Reported major air quality influences on surveyed Class I areas

Air quality influences	FWS[1]	FS[1]	NPS[1]	All
None	5	16	2	23
Regional haze	—	13	5	18
Industry	4	—	—	4
Mining	1	6	1	7
Powerplants	2	4	1	7
Urban sources	4	14	6	24
Mills	—	5	5	10
Other	7	21	5	33

[1] FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

industry sources were the most frequently mentioned by the Fish and Wildlife Service. The next most important sources, in descending order, were mills, mining, and powerplants. The "other" category included wildfire, prescribed burning, and agricultural dust. Whether wildfire and prescribed burning, from an air quality point of view, are significant factors affecting ecological systems in wildernesses is not known. However, these factors, along with agricultural dust, were the most frequently identified as affecting air quality (table 17). Their influence on visibility is known. Twenty-three managers were not aware of any air pollution influence on their Class I lands.

When questioned about documented ecological effects, the majority of Federal land managers indicated that they were unaware of such effects; only 20 percent indicated the availability of any records (table 14). This was particularly true for both the Fish and Wildlife Service and Forest Service. Twelve of 15 Park Service units contacted indicated that they had documented effects reflecting a decline in conditions and the number of sponsored research programs.

There was greater involvement in the PSD process than in documenting effects, possibly indicating concern about future pressures from development. A greater proportion of Fish and Wildlife Service and Park Service units had been involved in PSD review than the Forest Service (table 18). The Air Quality Division of the National Park Service acts as a centralized receiving group for PSD applications involving their Class I areas. They also assist the Fish and Wildlife Service in this review. Table 18 indicates that about one-quarter of the Class I areas surveyed have been involved in the PSD process. This is a conservative estimate because not all National Park Service Class I areas were surveyed. Since 1977, the Air Quality Division has reviewed more than 120 PSD permit applications for Park Service lands and 30 to 35 for Fish and Wildlife Service land (Scruggs 1985). Information was not available as to how many Class I areas these reviews represented except that a number have been for the same Class I areas over the last 10 years. As mentioned earlier, Forest Service personnel contacted were less familiar with the PSD process than were NPS and FWS personnel.

Table 18.—Prevention of significant deterioration (PSD) reviews involving Class I areas in survey

PSD review	FWS[1]	FS[1]	NPS[1,2]	All
Yes	6	13	7	26
No	11	42	7	60
Unknown	0	10	1	11

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

[2]Only a portion of NPS Class I areas surveyed.

Most of the Federal land managers did identify some AQRV's for their Class I lands (table 19). Of those that did, the majority identified the visibility AQRV. This AQRV is an indicator that has been specifically promoted by EPA. The Forest Service and the Park Service have identified a number of other AQRV's including flora and fauna, wildlife, fisheries, odor, and geology.

Table 19.—Identified air quality related values (AQRV's) of surveyed Class I areas

AQRV's	FWS[1]	FS[1]	NPS[1]	All
None	10	44	3	57
Visibility	7	19	12	38
Wildlife	—	6	3	9
Flora/fauna	1	7	4	12
Fisheries	—	3	2	5
Odor	—	4	—	4
Geology	—	3	—	3
Other	—	4	1	5

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

The results of our survey indicated that the primary research and monitoring presently being conducted in Class I areas is related to visibility. Ecological research related to air pollution effects in wildernesses is limited to only a few Class I areas (less than 15 percent) and deals primarily with the responses of selected sensitive plant species. Excluding visibility studies, the most ecological research associated with wildernesses is carried out by the National Park Service and the least by the Fish and Wildlife Service. However, this is influenced in part by the fact that these two Federal agencies have a memorandum of understanding for air quality activity, with the work being conducted through the Air Quality Division of National Park Service.

AIR QUALITY/WILDERNESS ISSUES AND RESEARCH NEEDS

Detection or even recognition of change or damage in wildernesses presents a challenge to scientists. Distinguishing ecotoxic effects is difficult even in systems that can routinely and easily be monitored or otherwise instrumented for study (Butler 1978; Sheehan and others 1984), but the definition of wilderness and its inherent restrictions provide particular problems for scientific study. Not only must spatial and temporal variation be monitored, but detection of fluctuation outside of the norm must be determined for both acute and chronic situations of air quality degradation. This must be accomplished without impact on the wilderness concept. Without this information, the manager is unable to determine what effects are taking place or what potential effects may occur under certain air quality scenarios. Given the recorded effects and sensitivity of National Park ecosystems to air pollution (Bennett and others, this proceedings), some wildernesses can be expected to be affected by regional air pollution. Basic air quality monitoring information is still lacking for wildernesses and existing air pollution models are not accurate for the long distances associated with transport of pollutants.

Detailed studies in surrogate ecosystems and remote sensing or other forms of nonintrusive monitoring may provide alternatives for wilderness research. Variables to be measured or monitored should focus on those indicative of the overall condition of the ecosystem and comparable over a variety of ecosystems. These should be easily and reliably measured and related to variables used in quantitative or modeling studies (Miller 1984). Because of their usual remoteness, wildernesses are most likely to encounter sublethal stress from air pollutants rather than acute effects. Therefore, the study of bioaccumulative responses is perhaps of highest priority. Techniques must be capable of addressing the mixture of air pollutants that is likely to exist (oxidants and sulfates, for instance), rather than the single-species response to an individual air pollutant. Methodology must be directed toward ecosystem scale analysis (Myers and Shelton 1980).

The complexity of the air quality issue in wildernesses has been indicated in a number of recent situations. Perhaps one of the most pertinent involved the Boundary Waters Canoe Area Wilderness (BWCA) and the Voyageurs National Park (VNP). An 800-megawatt, coal-fired powerplant was proposed for construction in Ontario, Canada, about 38 miles from the northern edge of the BWCA in Minnesota. The situation involved potential transfer of air pollutants across an international border and potential effects in these pristine ecosystems (Glass and Loucks 1980). This controversial case is particularly interesting because it not only involved a wilderness but was one of the first to deal with the deposition pattern of emissions from a point source and the use of a time-varying grid model with provisions for atmospheric transformation (acid precipitation). Although the powerplant was not built, the case pointed out the difficulty in determining sensitive receptors and predicting significant consequences of potential increased loadings of sulfuric and nitric acids and other combustion byproducts at distant sites.

Although potential point source effects on wildernesses can be regulated, the growing air quality impact of regional nonpoint source pollution, such as acid rain or oxidants, is not regulated. States, EPA, and Federal land management agencies need to address this problem if regional air quality effects of certain wildernesses (as well as other protected areas such as national parks) are to be minimized or eliminated. Also there is no mechanism for revising the PSD decision if new data become available indicating different air quality conditions (Yuhnke, this proceedings).

Research to determine sensitive receptors may in itself create a problem. For example, as part of the Federal research effort to assess the current and potential impact of acid deposition, a national surface water survey is underway (Brakke and others 1985). This three-phase project seeks to document the chemical and biological status of a representative sample of lakes and streams. To be representative, the sampling must include some wildernesses, but because the sampling approach may include use of motorized equipment or aircraft, there are potential conflicts with the strict application of the wilderness concept. In Washington State, for example, 59 of the 131 lakes proposed for sampling are in wildernesses. Access, even for scientific purposes and potential benefit, may establish an undesirable precedent.

The importance of this type of research, monitoring, and establishment of baseline conditions in wildernesses is evident again when attempting to determine "adverse impacts." In the case of the Clean Air Act and its amendments, the definition of adverse impact is left to the Federal land manager. The dilemma, then, is one of detecting and quantifying an effect without imposing on the naturalness of the area. The most sensitive receptors must first be identified. In wildernesses this may be difficult because there is often a paucity of air quality-related information on species most likely to be impacted, those in the alpine and subalpine life zones (Haddow 1984). If the information is available, there must then be a determination of "adverse" effects. Rocky Mountain and Intermountain Regions of the Forest Service have adopted a position of identifying a level of acceptable change (LAC) for each sensitive receptor for each air quality-related value in a wilderness. They interpret any predicted or measured change exceeding the LAC as adverse (Haddow 1984). This strict interpretation that any measurable effect is adverse will require careful selection and development of sensitive receptor monitoring systems. A recent Forest Service workshop dealt with these questions (USDA FS 1984).

The survey of Federal land managers of Class I lands, including a number of wilderness areas, reveals an uneven understanding by the managers of air quality effects, including the legislated authority to evaluate and protect sensitive environmental resources in their jurisdiction. Managers need training in basic air quality effects considerations, monitoring, and bioindicator theory. In addition, the need for a better understanding of the manager's role in the PSD review process is evident. Overall, very little progress has been made, except for the visibility AQRV, in developing and identifying AQRV's for Class I wildernesses. We suggest that such a system must be developed if these areas are to be adequately protected as prescribed by the Wilderness Act. The direction the Forest Service is taking in developing protocols for subalpine areas is a good model (Fox, this proceedings) and might be extended to all wilderness ecosystems.

Redesignation of Class II wildernesses to Class I status needs consideration. Presently Class I wilderness is afforded greater protection than Class II areas, although the policy of the Wilderness Act that created all wildernesses requires the most stringent protection of environmental quality, including the air resource. A potential policy conflict exists in enforcement of wilderness protection, Class II areas, and the Clean Air Act.

This conference and the creation of a National Wilderness Research Foundation are important steps in developing the research and information to meet these needs. Coordination of research efforts among Federal agencies, States, and the private sector is critical. Precedent for this type of integration is set by the current Federal interagency research program on acid precipitation and the interagency cooperation between the National Park Service and the Fish and Wildlife Service on air quality permit reviews. Developing a network of cooperative and coordinated projects will enhance opportunities for long-term support of both research and monitoring activities, which are necessary for impact analyses and ensuring preservation of wildernesses.

ACKNOWLEDGMENTS

We would like to thank the following reviewers for their time and helpful comments: Carole Goodyear and Rita Villella, Eastern Energy and Land Use Team, Fish and Wildlife Service; Paul Opler, Office of Information Transfer, Fish and Wildlife Service; and Robin Hart, Environmental Science and Engineering, Inc. We also appreciate the time and effort of Priscilla Branson, Eastern Energy and Land Use Team, in typing the various drafts.

REFERENCES

Anonymous. New 5-year national plan for biosphere reserves. Athens, GA: International Association of Ecology, Athens Observer; Newsletter. 15: 3; 1985.

Altshuller, A. P.; Linthurst, R. A., eds. The acidic deposition phenomenon and its effects. Critical Assessment Review Papers. EPA-600/8-83-016B. Washington, DC: U.S. Environmental Protection Agency; 1984. 700 p.

Applied Science Associates, Inc. Diagnosing vegetation injury caused by air pollution. EPA-450/3-78-005. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards, Control Programs Development Division; 1978. 234 p. plus appendixes.

Armentano, T. V.; Loucks, O. L. Air pollution threats to U.S. national parks of the Great Lakes region. Environ. Conserv. 10: 303-313; 1983.

Auerbach, S. I. Ecosystem response to stress: a review of concepts and approaches. In: Barrett, G. W.; Rosenberg, R., eds. Stress effects on natural ecosystems. New York: John Wiley and Sons; 1981: 29-41.

Avery, M.; Schreiber, R. K. The Clean Air Act: its relation to fish and wildlife resources. FWS/OBS-76/20.8. Washington, DC: U.S. Fish and Wildlife Service; 1979. 14 p.

Baker, J. P.; Driscoll, C. T.; Fischer, K. L.; [and others]. Effects on aquatic biology. In: Altshuller, A. P.; Linthurst, R. A., eds. The acidic deposition phenomenon and its effects. Critical Assessment Review Papers. EPA-600/8-83-016B. Washington, DC: U.S. Environmental Protection Agency; 1984: 5-1—5-196.

Bennett, J. P. [Personal communication]. 1985a September. Located at: U.S. Department of the Interior, National Park Service, Air Quality Division, Denver, CO.

Bennett, J. P. Overview of air pollution in national parks in 1985. Park Sci. 5(4): 8-9; 1985b.

Bondietti, E.; Johnson, D. W.; Lindeberg, S. E.; [and others]. Integrated forest study on effects of atmospheric deposition. Project on effects of atmospheric deposition. Project Summary. Oak Ridge, TN: Oak Ridge National Laboratory; 1985 July. 35 p.

Brakke, D. F; Landers, D. H.; Linthurst, R. A.; Messer, J. The National Surface Water Survey studies lakes, streams. Lake Line. 5: 14-17; 1985.

Butler, G. C. Principles of ecotoxicology. SCOPE 12. New York: John Wiley and Sons; 1978. 350 p.

Carlson, C. E.; Dewey, J. E. Environmental pollution by fluorides in Flathead National Forest and Glacier National Park. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Insect and Disease Branch; 1971. 57 p.

Clark, K. L.; Fischer, K. Acid precipitation and wildlife. Draft Rep. No. 43. Ottawa, ON: Environment Canada, Canadian Wildlife Service; 1981. 53 p.

Cowling, E. B.; Linthurst, R. A. The acid precipitation phenomenon and its ecological consequences. Bioscience. 31: 649-654; 1981.

Davidson, C. I.; Goold, W. D.; Mathison, T. P.; [and others]. Airborne trace elements in Great Smoky Mountains, Olympic and Glacier National Parks. Environ. Sci. Tech. No. 1. 19: 27-35; 1985.

Dochinger, L. S.; Seliga, T. A., chairmen. Proceedings of the international symposium on acid precipitation and the forest ecosystem. Gen. Tech. Rep. NE-23. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1976. 1074 p.

Drablos, D.; Tollan, A., eds. Ecological impact of acid precipitation: Proceedings of an international conference; 1980 March 11-14; Sandefjord, Norway. Oslo, Norway: SNSF Project; 1980. 383 p.

Dvorak, A. J.; Lewis, B. G. Impacts of coal-fired plants on fish, wildlife, and their habitats. FWS/OBS-78/29. Washington, DC: U.S. Fish and Wildlife Service; 1978. 260 p.

Ecological Society of America. Symposium: indicators of ecosystem responses to fossil fuel residuals: annual meeting of the Ecological Society of America; 1980 August 16-20; Bloomington, IN. Bull. Ecol. Soc. Am. 62: 90-91, 107-108; 1981.

Eilers, J. M.; Lien, G. J.; Berg, R. G. Aquatic organisms in acidic environment: a literature review. Tech. Bull. 150. Madison, WI: Department of Natural Resources; 1984. 18 p.

Eriksson, M. O. G. Acidification of lakes: effects on waterbirds in Sweden. Ambio. 13: 260-262; 1984.

Eriksson, M. O. G. Prey detectability for fish-eating birds in relation to fish density and water transparency. Ornis Scandinavica. 16: 1-7; 1985.

Federal Register. 43(69): 15016; 1978.

Federal Register. 47(182): 44480-2; 1982.

Ferry, B. W.; Baddeley, M. S.; Hawkworth, D. L., eds. Air pollution and lichens. London: Athalone Press; 1973. 175 p.

Fischer, K. L. Acid precipitation and concerns for fish and wildlife resources. In: Markley, M., ed. Proceedings, 72nd convention of the International Association of Fish and Wildlife Agencies; 1982 September 19-22; Hilton Head Island, SC. Washington, DC: International Association of Fish and Wildlife Agencies; 1983: 19-35.

Fischer, K. L. Acid rain and wildlife. ESC-LRTAP Fact Sheet. Ottawa, ON: Canadian Wildlife Service; 1984. 9 p.

Fox, D. G.; Murphy, D. J.; Haddow, D., tech. coords. Air quality, oil shale, and wilderness—a workshop to identify and protect air quality related values of the Flat Tops. Gen. Tech. Rep. RM-91. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 32 p.

Franklin, J. [Personal communication]. 1985 September. Located at: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, OR.

Freedman, B.; Hutchinson, T. C. Pollution inputs from the atmosphere and accumulations in soils and vegetation near a nickel-copper smelter at Sudbury, Ontario, Canada. Can. J. Bot. 58: 108-132; 1980.

Fritz, E. S. Potential impacts of low pH on fish and fish populations. FWS/OBS-80/40.2. Washington, DC: U.S. Fish and Wildlife Service; 1980. 14 p.

Fromm, P. O. A review of some physiological and toxicological responses of freshwater fish to acid stress. Environ. Biol. Fish. 5: 79-93; 1980.

Galloway, J. N.; Anderson, D. S.; Church, M. R.; Gronon, C. S.; Davis, R. B.; Dillon, P. J.; Driscoll, C. T.; Norton, S. A.; Schofron, G. S. Effects on aquatic chemistry. In: Altshuller, A. P.; Linthurst, R. A., eds. The acidic deposition phenomenon and its effects. Critical Assessment Review Papers. EPA-600/8-83-016B. Washington, DC: U.S. Environmental Protection Agency; 1984: 4-1—4-197.

Gibson, J. H.; Galloway, J. N.; Schofield, C.; McFee, W.; Johnson, R.; McCarley, S.; Dise, N.; Herzog, D. Rocky Mountain acidification study. FWS/OBS-80/40.17. Kearneysville, WV: U.S. Fish and Wildlife Service; 1983. 137 p.

Glass, B. E.; Loucks, O. L. Impacts of airborne pollutants on wilderness areas along the Minnesota-Ontario border. EPA-600/3-80-044. Duluth, MN: U.S. Environmental Protection Agency; 1980. 186 p.

Gordon, A. G.; Gorham, E. Ecological aspects of air pollution from an iron sintering plant at Wawa, Ontario. Can. J. Bot. 41: 1063-1078; 1963.

Gorham, E. Air pollution from metal smelters. Naturalist. 21: 12-15; 1970.

Gorham, E.; Bayley, S. E.; Schindler, D. W. Ecological effects of acid deposition upon peatlands: a neglected field in "acid rain" research. Can. J. Fish. Aquatic Sci. 41: 1256-1268; 1984.

Grodzinski, W.; Weiner, J.; Maycock, P. F., eds. Forest ecosystems in industrial regions. New York: Springer-Verlag; 1984. 277 p.

Grodzinski, W.; Yorks, T. P. Species and ecosystem level bioindicators of airborne pollution: an analysis of two major studies. Water Air Soil Pollut. 16: 33-35; 1981.

Guderian, R. Air pollution: phytotoxicity of acidic gases and its significance in air pollution control. Ecological Studies 22. New York: Springer-Verlag; 1977. 277 p.

Haddow, D. Forest Service responsibilities in the PSD process. In: Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region, Air Quality Group; 1984: 22-28.

Haines, T. A. Acidic precipitation and its consequences for aquatic ecosystems: a review. Trans. Am. Fish Soc. 110: 79-93; 1981.

Haines, T. A.; Akielaszek, J. J. Effects of acidic precipitation on Atlantic salmon rivers in New England. FWS/OBS-80/40.18. Kearneysville, WV: U.S. Fish and Wildlife Service; 1984. 108 p.

Haines, T. A.; Johnson, R. E., eds. Acid rain-fisheries. Bethesda, MD: American Fisheries Society; 1982. 357 p.

Hale, M. E. A lichen biomonitoring program in the Bridger Wilderness. In: Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region, Air Quality Group; 1984: 208-236.

Halpin, P. Literature resources. In: Stern, A. C., ed. Air pollution. Vol. 2: The effects of air pollution. 3d ed. New York: Academic Press; 1977: 611-683.

Haywood, J. K. Injury to vegetation by smelter fumes. Bull. 89. Washington, DC: U.S. Department of Agriculture, Bureau of Chemistry; 1905. 23 p.

Haywood, J. K. Injury to vegetation and animal life by smelter wastes. Bull. 113. Washington, DC: U.S. Department of Agriculture, Bureau of Chemistry; 1910. 63 p.

Heagle, A. S. Effects of pollution on insects. In: Interaction between air pollutants and plant parasites. Annu. Rev. Phytopathol. 11: 381-382; 1973.

Heck, W. W. The use of plants as indicators of air pollution. Water Air Soil Pollut. 10: 99-111; 1966.

Heck, W. W.; Brandt, C. S. Effects on vegetation: native, crops, forests. In: Stern, A. C., ed. Air pollution. Vol. 2: The effects of air pollution. 3d ed. New York: Academic Press; 1977: 158-229.

Hendrey, G. R.; Galloway, J. N.; Norton, S. A.; Schofield, C. L.; Shaffer, P. W.; Burns, D. A. Geological and hydrochemical sensitivity of the eastern United States to acid precipitation. EPS-600/3-80-024. Upton, NY: Brookhaven National Laboratory; 1980. 90 p.

Hogan, G. D.; Wotton, D. L. Pollutant distribution and effects in forest adjacent to smelters. J. Environ. Qual. 13: 377-382; 1984.

Hursh, C. R. Local climate in the copper basin of Tennessee as modified by vegetation removal. Circular 774. Washington, DC: U.S. Department of Agriculture; 1948. 38 p.

Hutchinson, T. C.; Whitby, L. M. A study of airborne contamination of vegetation and soils by heavy metals from Sudbury, Ontario copper-nickel smelters. In: Hamphill, D. D., ed. Trace substances in environmental health, VII: a symposium. Columbia, MO: University of Missouri; 1974: 179-189.

Interagency Task Force on Acid Precipitation. National acid precipitation assessment plan. Washington, DC: Council on Environmental Quality; 1982. 92 p.

Jenkins, D. W. Biological monitoring of toxic trace metals. Vol. 1. Biological monitoring and surveillance. EPA-600/3-80-089. Las Vegas, NV: U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Office of Research and Development; 1980. 215 p.

Johnson, D. W.; Chevon, B. I.; Irving, P. M.; [and others]. Effects on vegetation. In: Altshuller, A. P.; Linthurst, R. A., eds. The acidic deposition phenomenon and its effects. Critical Assessment Review Papers. EPA-600/8-83-016B. Washington, DC: U.S. Environmental Protection Agency; 1984: 3-1—3-87.

Jones, U. S.; Hamilton, M. G.; Pitner, J. B. Atmospheric sulfur as related to fertility of Ultisols and Entisols in

South Carolina. Soil Sci. Soc. Am. J. 43: 1169-1171; 1979.

Kercher, J. R.; Axelrod, M. C. Analysis of SILVA: a model for forecasting the effects of SO_2 pollution and fire on western coniferous forests. Ecol. Model. 23: 165-184; 1984.

Kercher, J. R.; Axelrod, M. C.; Bingham, G. E. Hierarchical set of models for estimating the effects of air pollution on vegetation. In: Mitsh, W. J.; Bosserman, R. W.; Klopatch, J. M., eds. Energy and ecological modeling. Amsterdam: Elsevier Scientific; 1981: 401-409.

Kimball, T. L. Our national EQ: the first National Wildlife Federation index of environmental quality. Natl. Wildl. 7: 2-13; 1969.

Klein, R. M. Ecosystem approach to acid rain problem. In: Linthurst, R. A., ed. Direct and indirect effects of acidic deposition on vegetation. Acid Precipitation Series Vol. 5. Stoneham, MA: Butterworth; 1984: 1-11.

Lauenroth, W. K.; Preston, E. M., eds. The effects of SO_2 on a grassland: a case study in the northern Great Plains of the United States. New York: Springer-Verlag; 1984. 107 p.

LeBlanc, F.; Rao, D. N. Effects of air pollutants on lichens and bryophytes. In: Mudd, J. B.; Kozlowski, T. T., eds. Responses of plants to air pollution. New York: Academic Press; 1975: 237-272.

Lefohn, A. S.; Brocksen, R. W. Acid rain research—a status report. J. Air Pollut. Control Assoc. 34: 1005-1113; 1984.

Lefohn, A. S.; Klock, G. O. The possible importance of forest soil processes in defining surface water pH relationships. J. Air Pollut. Control Assoc. 35: 632-637; 1985.

Lefohn, A. S.; Ormrod, D. P. A review and assessment of the effects of pollutant mixtures on vegetation-research recommendations. EPA-600/3-84-037. Corvallis, OR: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory; 1984. 104 p.

Lippincott, W. S.; Baron, J.; Herrmann, R. Status report: acid rain research in the National Park Service. WFRSL Rep. 82-1. Fort Collins, CO: National Park Service, Water Resources Field Support Laboratory; 1982. 29 p.

Little, P.; Martin, H. A survey of zinc, lead, and cadmium in soil and natural vegetation around a smelting complex. Environ. Pollut. 3: 245-254; 1972.

Loucks, O. L.; Miller, R. W.; Armentano, T. V. An assessment of aquatic resources altered or at risk from acidic deposition. Northeast. Environ. Sci. 3: 8-23; 1984.

Luxmoore, R. Modeling pollutant uptake and effects on the soil-plant litter system. In: Miller, P. R., ed. Proceedings of the symposium on the effects of air pollutants on mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 174-180.

Mayer, K. S.; Multer, E.; Schreiber, R. K. Acid rain: effects on fish and wildlife. Fish and Wildlife Leaflet 1. Washington, DC: U.S. Fish and Wildlife Service; 1984. 9 p.

McFee, W. W.; Adams, F.; Cronan, C. S.; Firestone, M.; Foy, C. D.; Harter, R. D.; Johnson, D. W. Effects on soil systems. In: Altshuller, A. P.; Linthurst, R. A., eds. Acidic deposition phenomenon and its effects. Critical Assessment Review Papers. EPA-600/8-83-016B. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development; 1984: 2-1—2-73.

McLaughlin, S. B. Effects of air pollution on forest: a critical review. J. Air Pollut. Control Assoc. 35: 512-532; 1985.

Miller, D. R. Distinguishing ecotoxic effects. In: Sheehan, P. J.; Miller, D. R.; Butler, G. C.; Bourdeau, P., eds. Effects of pollutants at the ecosystem level. Scientific Committee on Problems of the Environment. SCOPE 22. New York: John Wiley and Sons; 1984: 5-22.

Miller, J. M., ed. The potential atmospheric impact of chemicals released to the environment. EPA-560/5-80-001. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances; 1981. 229 p.

Miller, P. R., ed. Proceedings of the symposium on the effects of air pollutants on mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980. 256 p.

Miller, P. R. Ozone effects in the San Bernardino National Forest. In: Davis, D. D.; Millen, A. A.; Dochinger, L., eds. Proceedings of the symposium on air pollution and the productivity of the forest; 1983 October 4-5; Washington, DC. Arlington, VA: Izaak Walton League of America; 1983. 344 p.

Miller, P. R.; Elderman, M. J., eds. Photochemical oxidant air pollution effects on a mixed conifer forest ecosystem: a progress report. EPA-600/3-77-104. Corvallis, OR: U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Office of Research and Development; 1977. 338 p.

Minnesota Environmental Quality Board. Development of a biological air quality indexing system. St. Paul, MN: Minnesota Environmental Quality Board, Power Siting Program; 1984. 380 p.

Mudd, J. B.; Kozlowski, T. T., eds. Responses of plants to air pollution. New York: Academic Press; 1975. 383 p.

Myers, W. L.; Shelton, R. L. Survey methods for ecosystem management. New York: John Wiley and Sons; 1980. 403 p.

National Academy of Science. Atmosphere-biosphere interactions: toward a better understanding of the ecological consequences of fossil fuel combustion. Washington, DC: Committee on the Atmosphere and Biosphere, National Academy Press; 1981. 263 p.

National Research Council Canada [NRCC]. Acidification in the Canadian aquatic environment: scientific criteria for assessing the effects of acidic deposition on aquatic ecosystems. NRCC No. 18475. Ottawa, Canada; 1981. 369 p.

Newman, J.; Schreiber, K.; Jensen, L.; Rios, B.; Sarazin, J. Fish and wildlife. In: Fox, D. G.; Murphy, D. J.; Haddow, D., tech. coords. Air quality, oil shale, and wilderness—a workshop to identify and protect air quality related values of the Flat Tops. Gen.

Tech. Rep. RM-91. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981: 13-17.

Newman, J. R. Animal indicators of air pollution: a review and recommendations. Rep. CERL-006. Corvallis, OR: U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory; 1975. 192 p.

Newman, J. R. Effects of air emissions on wildlife resources. FWS/OBS-80/40.1. Washington, DC: U.S. Fish and Wildlife Service; 1980. 32 p.

Newman, J. R.; Schreiber, R. K. Animals as indicators of ecosystems responses to air emissions. Environ. Manage. 8: 309-324; 1984.

Newman, J. R.; Schreiber, R. K. Effects of acidic deposition and other energy emissions on wildlife: a compendium. Vet. and Human Toxicol. 27: 394-401; 1985.

Newman, J. R.; Novakova, E.; McClave, J. T. The influence of industrial air emissions on the nesting ecology of the house martin, *Delichon urbica*, in Czechoslovakia. Biol. Conserv. 31: 229-248; 1985.

Nriagu, J. O. Environmental impacts of smelters. New York: John Wiley and Sons; 1984. 608 p.

Nyholm, N. E. Evidence of involvement of aluminum in causation of defective formation of eggshells and of impaired breeding in wild passerine birds. Environ. Res. 26: 363-371; 1981.

Office of Technology Assessment [OTA]. Acid rain and transported air pollutants. Implications for public policy: summary. Washington, DC: Congress of the United States; 1984. 35 p.

Perley, M.; Fischer, K. Acid rain: a crisis for animals. Animals. 116: 7-9; 1983.

Peterson, M. A.; Adler, D. The effects of air pollution and acid rain on fish, wildlife, and their habitats: introduction. FWS/OBS-80/40.3. Washington, DC: U.S. Fish and Wildlife Service; 1982. 180 p.

Pfeiffer, M. H.; Festa, P. J. Acidity status of lakes in the Adirondack region of New York in relation to fish resources. FW-P168(10/80). Albany, NY: New York State Department of Environmental Conservation; 1980. 36 p.

Pierce, B. A. Acid tolerance in amphibians. Bioscience. 35: 239-243; 1985.

Postel, S. Air pollution, acid rain, and the future of forest. Worldwatch Paper 58. Washington, DC: Worldwatch Institute; 1984. 54 p.

Potter, W.; Adler, D. The effects of air pollution and acid rain on fish, wildlife, and their habitats: lakes. FWS/OBS-80/40.4. Washington, DC: U.S. Fish and Wildlife Service; 1982. 121 p.

Potter, W.; Chang, B. K-Y; Adler, D. The effects of air pollution and acid rain on fish, wildlife, and their habitats: rivers and streams. FWS/OBS-80/40.5. Washington, DC: U.S. Fish and Wildlife Service; 1982. 52 p.

Roth, P.; Blanchard, C.; Harte, J.; Michaels, H.; El-Ashry, M. T. The American Wests acid rain test. Res. Rep. 1. Washington, DC: World Resources Institute; 1985. 50 p.

Runeckles, V. A. Impact of air pollutant combinations on plants. In: Treshow, M. Air pollution and plant life. New York: John Wiley and Sons; 1984: 239-258.

Schreiber, R. K.; Fischer, K. L. Acid stress on forest habitats: implications for terrestrial wildlife: Symposium proceedings; 1983 June 14-17; Quebec City, PQ. Quebec City, PQ: Canadian Forestry Service and U.S. Department of Agriculture, Forest Service; [in press].

Schreiber, R. K.; Villella, R. Influence of airborne pollutants on forest wildlife. In: Air pollutants effects on forest ecosystems: Symposium proceedings; 1985 May 8-9; St. Paul, MN. St. Paul, MN: Acid Rain Foundation; 1985: 267-284.

Scruggs, M. [Personal communication]. 1985 September. Located at: U.S. Department of the Interior, National Park Service, Air Quality Division, Denver, CO.

Sheehan, P. J.; Miller, D. R.; Butler, G. C.; Bourdeau, P., eds. Effects of pollutants at the ecosystem level. Scientific Committee on Problems of the Environment. SCOPE 22. New York: John Wiley and Sons; 1984. 443 p.

Shugart, H. A.; McLaughlin, S. B.; West, D. C. Forest models: their development and potential applications for air pollution effects research. In: Miller, P. R., ed. Proceedings of the symposium on the effects of air pollutants on mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 203-214.

Skye, E. Lichens as biological indicators of air pollution. Annu. Rev. Phytopathol. 17: 325-341; 1979.

Smith, W. H. Air pollution and forests. New York: Springer-Verlag; 1981. 379 p.

Smith, W. H. Evidence for effects of air pollution on the northeastern forest. In: Air pollutants effects on forest ecosystems: Symposium proceedings; 1985 May 8-9; St. Paul, MN. St. Paul, MN: Acid Rain Foundation; 1985: 123-135.

Soholt, L. F.; Wiedenbaum, S. Oil shale: its development and potential for air quality effects. FWS/OBS-81/34. Washington, DC: U.S. Fish and Wildlife Service; 1981. 62 p

Suter, G. W. Ecosystem theory and NEPA assessment. Bull. Ecol. Soc. Am. 62: 186-192; 1981.

Swedish Ministry of Agriculture. Acidification today and tomorrow. Stockholm, Sweden: Swedish Ministry of Agriculture, Environment '82 Committee; 1982. 231 p.

Tetra Tech, Inc. The integrated lake-watershed acidification study. Vol. 4: Summary of major results. EPRI EA 3221. Palo Alto, CA: Electric Power Research Institute, Ecological Studies Program, Energy Analysis and Environment Division; 1984. 199 p.

Tome, M. A.; Pough, F. H. Responses of amphibians to acid precipitation. In: Haines, T. A.; Johnson, R. E., eds. Acid rain-fisheries. Bethesda, MD: American Fisheries Society; 1982: 245-254.

Treshow, M. Air pollution and plant life. New York: John Wiley and Sons; 1984. 486 p.

Ulrich, B. Stability and destabilization of central European forest ecosystems: a theoretical, data-based approach. Intecol. Bull. 9: 37-42; 1983.

Ulrich, B.; Pankrath, J. Effects of accumulations of air pollutants on forest ecosystems. Dordrecht, Netherlands: D. Reidel Publishing; 1983. 389 p.

U.S. Department of Agriculture, Forest Service. Workshop proceedings: air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1984. 292 p.

U.S. Environmental Protection Agency; Environment Canada. Memorandum of intent on transboundary air pollution. Final report. Washington, DC: U.S. Environmental Protection Agency-Environment Canada, Impact Assessment Work Group 1; 1983. 626 p.

Wiener, J. G. Comparative analyses of fish populations in naturally acidic and circumneutral lakes in northern Wisconsin. FWS/OBS-80/40.16. Kearneysville, WV: U.S. Fish and Wildlife Service; 1983. 107 p.

Wiersma, G. B. Recommended integrated monitoring system for pollutants on U.S. National Parks designated as biosphere reserves. EGG-PBS-6721. Idaho Falls, ID: U.S. Department of Energy, Idaho National Engineering Laboratory; 1985 January. 82 p.

Wiersma, G. B.; Brown, K. W. Background levels of trace elements in forest ecosystems. In: Miller, P. R., ed. Proceedings of the symposium on the effects of air pollutants on mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 31-37.

Wiersma, G. B.; Brown, K. W.; Crockett, A. B. Development of a pollutant monitoring system for biosphere reserves. EPA-600/4-78-052. Las Vegas, NV: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory; 1978. 113 p.

Wilhour, R. G. Effects of acidic deposition on aquatic and terrestrial resources. Corvallis, OR: Environmental Protection Agency, Corvallis Environmental Research Laboratory; 1985. 28 p.

Woodwell, G. M. Effects of pollution on the structure and physiology of ecosystems. Science. 168: 429-433; 1970.

APPENDIX: LIST OF CLASS I AREAS SURVEYED

Responsible Agency	Class I area
U.S. Fish and Wildlife Service	Chassahowitzka
	St. Marks
	Okefenokee
	Breton
	Mingo
	Swanquarter
	Cape Romain
	Red Rock Lakes
	Medicine Lake
	U.L. Bend
	Wichita Mountains
	Bosque del Apache
	Salt Creek
	Seney
	Lostwood
	Brigantine
	Bering Sea

(con.)

Responsible Agency	Class I area
National Park Service	Glacier
	Grand Teton
	Yellowstone
	Zion
	Craters of the Moon
	Shenandoah
	Voyageurs
	Grand Canyon
	Sequoia
	Acadia
	Bandelier
	Everglades
	Great Smoky Mountains

Forest Service	**Forest**	**Area**
	Nez Perce	Hells Canyon
	Sawtooth	Sawtooth
	Beaverhead	Anaconda-Pintlar
	Flathead	Bob Marshall
		Mission Mountains
	Kootenai	Cabinet Mountains
	Helena	Gates of the Mountain
		Scapegoat
	Bitterroot	Selway-Bitterroot
	Tonto	Mazatzal
		Sierra Ancha
		Superstition
		Pine Mountain
	Coconino	Sycamore Canyon
	Gila	Gila
	Carson	Pecos
	Lincoln	White Mountain
	Santa Fe	San Pedro Parks
	White River	Eagles Nest
		Flat Tops
		Maroon Bells
	Gunnison	LaGarita
		West Elk
	Routt	Mount Zirkel
		Rawah
	Rio Grande	Weminuche
	Fremont	Gearhart Mountain
	Siskiyou	Wild Rogue
		Kalmiopsis
	Winema	Mountain Lakes
	Mt. Hood	Mt. Hood
	Umatilla	Wenaha-Tucannon
	Mt. Baker-Snoqualmie	Alpine Lakes
	Okanogan	Pasayten
	Gifford Pinchot	Mount Adams
		Goat Rocks
	Cleveland	Agua Tibia
	Lassen	Caribou
	Sequoia	Dome Land
	Eldorado	Desolation
		Mokelumne
	Stanislaus	Emigrant
	Inyo	Hoover
	Sierra	John Muir
		Kaiser
	Klamath	Marble Mountain
	Modoc	South Warner
	Mendocino	Yolla Bolly-Middle Eel

(con.)

Responsible Agency		Class I area
Forest Service	**Forest**	**Area**
	Superior	Boundary Waters Canoe Area
	Mark Twain	Hercules-Glades
	White Mountain	Great Gulf
		Presidential Range
	Green Mountain	Lye Brook
	Monongahela	Dolly Sods
	Bankhead	Sipsey
	Ouachita	Caney Creek
	Ozark	Upper Buffalo
	Apalachicola	Bradwell Bay
	Chattahoochee	Cohutta
	Pisgah	Linville Gorge
		Shining Rock
	Cherokee	Joyce Kilmer-Slickrock
	Jefferson	James River Face

AUTHOR

R. Kent Schreiber
Supervisory Ecologist
National Ecology Center
U.S. Fish and Wildlife Service, USDI
Kearneysville, WV 25430

James R. Newman
Vice President/Principal Scientist
KBN Engineering and Applied Sciences, Inc.
Gainesville, FL 32604

RESEARCH ON SOIL AND VEGETATION IN WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

David N. Cole

ABSTRACT

This paper deals primarily with research on soil and vegetation impacts caused by recreational use of wilderness. Studies have documented the most obvious effects of trampling, described conditions on campsites and along trails, described the spatial distribution of impact, and documented changes in impact levels over time. Relatively little is known about the effect of trampling on soil biota and plant physiology or the impact of recreational stock. Lack of theoretical work and the short time frames of most studies leave us with little ability to evaluate the significance of most of the impacts that have been described. An increasing number of studies have examined the importance of factors that influence amount of impact. A considerable amount of research on the relationship between amount of use and amount of impact has consistently shown the relationship to be highly curvilinear. Impact generally occurs rapidly and can be severe even on lightly used sites. The exact nature of this relationship varies with type of use, environmental conditions, and impact parameter. Different environments vary considerably in their resistance and their resilience. Few studies have differentiated impact by type of user, however. There has also been a limited amount of applied management-oriented impact research, mostly in the areas of development of monitoring techniques and experimentation with techniques for rehabilitating damaged recreation sites. There is a need for more longitudinal studies, more specialized, detailed studies, more interdisciplinary approaches, and an expanded regional coverage. Current high-priority research needs are identified. Such studies are unlikely to be conducted until careers in the field become available.

INTRODUCTION

Wilderness soil and vegetation have been the subject of two rather distinct types of research. In the first type, natural soil and vegetation conditions and processes are studied. The primary objective of this line of research is to improve our understanding of the structure and function of natural ecosystems. The second type of research is focused more narrowly on human-caused changes in soil and vegetation conditions in wilderness and how best to manage these impacts. The primary objective of this second type is to help managers with the difficult task of preserving natural conditions in wilderness. Major agents of change in wilderness include air pollution, fire, nonrecreational grazing, mining, introduced plants and animals, and recreational use. Many of these research topics are discussed in detail in review papers on basic ecological processes, air, fire, and fish and wildlife; others have been the subject of very little research. I will only briefly comment on and cite a few examples of most of these lines of research and focus primarily on research on the impact of recreational use on soils and vegetation (fig. 1).

RESEARCH ON WILDERNESS SOIL AND VEGETATION CONDITIONS AND PROCESSES

Wilderness has been used as a natural laboratory for studying undisturbed soil and vegetation conditions and processes. (Throughout this paper, when I use the term "wilderness" I mean both legally designated wilderness and large nonroaded areas.) Due to their large size and a management regime that stresses preservation of natural conditions, wildernesses provide unique opportunities for basic biological research. Wilderness is particularly valuable for research that seeks to integrate complex elements of the ecosystem or that aims to classify and characterize natural plant communities. But wilderness is also an appropriate location for detailed, small-scale studies. For example, topics of papers presented at the Second Conference on Scientific Research in the National Parks ranged from extensive integrative studies (such as "Interactions Among Fluvial Processes, Forest Vegetation, and Aquatic Ecosystems, South Fork Hoh River, Olympic National Park, Washington") to small-scale studies (such as "Demography of *Salix setchelliana*—a Prostrate Willow of Alaskan Gravel Bars").

In most cases, studies are conducted in wilderness because wilderness provides the best opportunities for studying minimally disturbed soil/vegetation components. Undisturbed wilderness conditions also provide a baseline for evaluating the nature of human influences outside wilderness. The primary object of study is not the wilderness as such, but conditions that increasingly can only be found in wilderness. This is a major feature distinguishing this type of research from impact-oriented research. Such research can contribute to improved management of wilderness, however, even if this is not the primary goal. An improved understanding of the structure and function of natural ecosystems helps managers evaluate the significance of human disturbances.

Some of the best examples of basic ecological research that both capitalize on the unique characteristics of wilderness and also strive to make results applicable to management are the "pulse" studies that Jerry Franklin

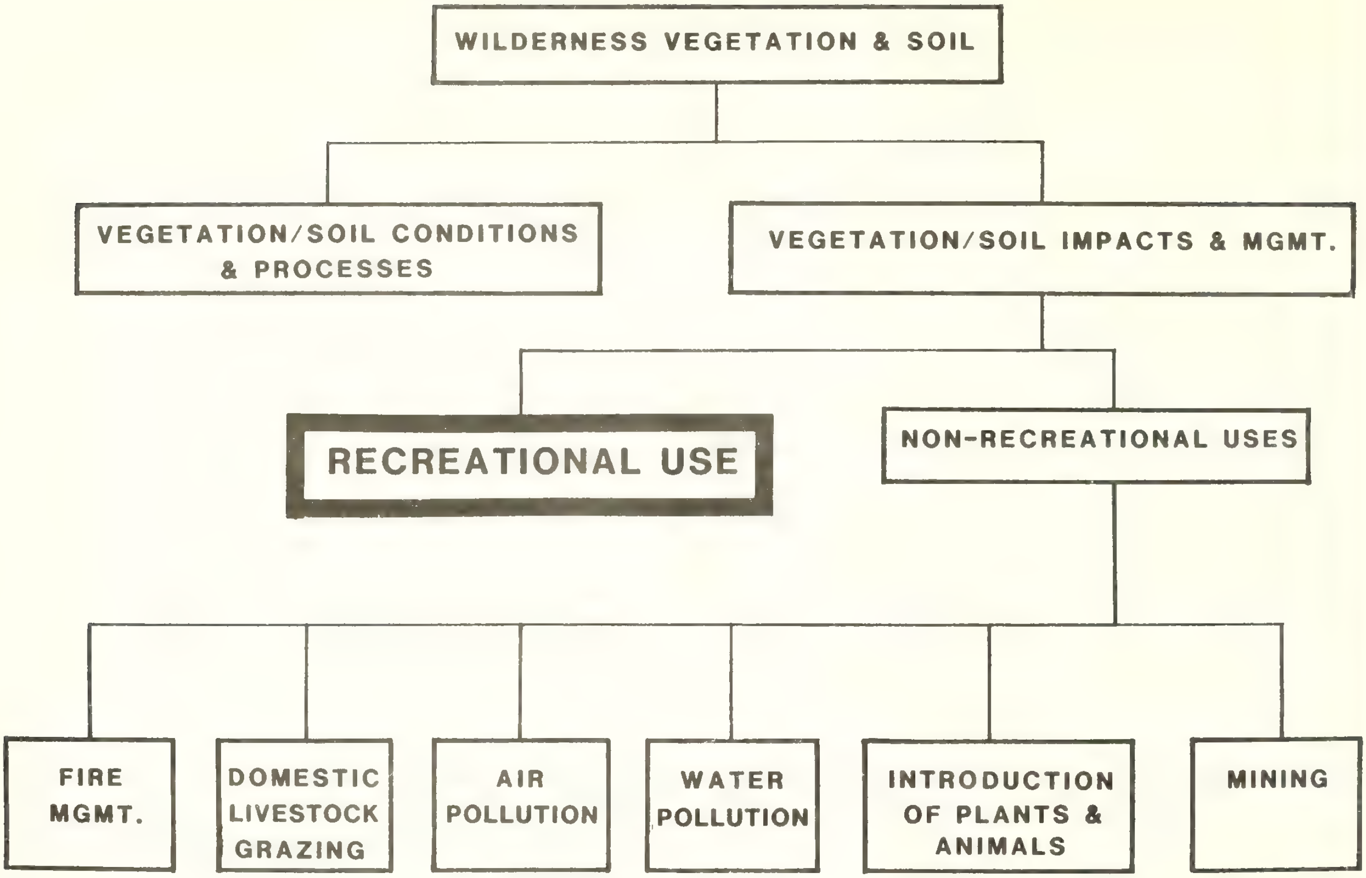

WILDERNESS VEGETATION & SOIL
VEGETATION/SOIL CONDITIONS & PROCESSES
VEGETATION/SOIL IMPACTS & MGMT.
RECREATIONAL USE
NON-RECREATIONAL USES
FIRE MGMT.
DOMESTIC LIVESTOCK GRAZING
AIR POLLUTION
WATER POLLUTION
INTRODUCTION OF PLANTS & ANIMALS
MINING

Figure 1.—Major types of research under the general heading of research on wilderness vegetation and soil.

has directed in Olympic and Sequoia/Kings Canyon National Parks. These studies bring together scores of specialists to measure, monitor, record, and then interact in such a way that linkages between ecosystem components are highlighted. Both studies have provided a wealth of basic ecological information. The Olympic study, for example, furthered the emerging recognition of the significant functions of woody debris—both on land and in stream channels—and provided a better understanding of disturbance agents in an environment that had been inadequately studied (Franklin and others 1982). A better understanding of the importance of woody debris as a seedbed and the effects of Roosevelt elk grazing on vegetation will help Park managers in their attempts to preserve natural conditions.

Most basic ecological research in wilderness could contribute to improved wilderness management. To maximize these benefits, however, communication between managers and researchers needs to be improved. Researchers can help by identifying potential management applications in the study design phase and by striving to highlight management implications. Managers can help by identifying information needs and communicating these to researchers.

Beyond these studies that contribute—often serendipitously—to management, all wildernesses need baseline and inventory information. Information is needed to (1) classify ecosystems, (2) map their distribution, (3) describe their basic characteristics, and (4) identify their dynamic properties and the factors affecting their dynamics (Franklin 1978). Information of this type is scarce. One of the few places where such information has been collected in a systematic manner is at Mount Rainier National Park (Moir and others 1979). A number of other National Parks have vegetation maps, data characterizing vegetation types, and permanent plots for monitoring trends, but other agencies with wilderness management responsibilities have little information of this type. The Forest Service, for example, is heavily involved in classifying vegetation in roaded areas and spends large sums of money every year for timber stand examinations and inventory. But little of this effort is directed toward wilderness, despite specific direction in the Forest Service Manual (FSM 2322.1) stating that wilderness management plans will (1) "describe the current condition of all resources and biotic associations"; (2) "describe the interrelationships of all resources, existing uses and activities, and highlight unique ecological situations"; and (3) "identify problems associated with maintaining an enduring wilderness resource and the reasons for the problem."

Of particular utility to management would be a classification system stratifying the land into units that respond similarly to disturbance agents that managers might want to control. Since susceptibility to disturbance varies greatly across the landscape, managers must understand and be able to communicate this variability. In an attempt to parallel current efforts by foresters to develop timber management guidelines for different habitat types (see, for example, Pfister and others 1977), Cole (1982a) classified the vegetation of a portion of the Eagle Cap Wilderness in Oregon. Drawing on observations, vegetation sampling along trails and in campsites, and analysis of stand structure, each vegetation type was characterized as to its suitability for trails and campsites, the likely effects of fire suppression, site rehabilitation potential, and other likely management problems. Although limited in scope, this attempt illustrates the potential value of a land stratification system for organizing and communicating information on how best to manage various land types.

Another attempt to incorporate knowledge about the capabilities of different land types comes from Sequoia/Kings Canyon National Parks. Meadow types were classified and then studied to determine their potential to support recreational grazing (DeBenedetti and Parsons 1983). As a result of this research, Park managers have proposed a recreational grazing plan that (1) is sensitive to annual variation in climate, (2) considers the nature of specific meadows, and (3) is sensitive to the inherent ability of individual species to withstand grazing and trampling. Other offshoots of the program that will become increasingly valuable with time are a monitoring program and the designation of selected meadows representative of each major meadow type to be protected from all stock use, to serve as benchmarks for comparison with grazed meadows.

Clearly there is much value in basic research into ecological conditions and processes—both to the advancement of biology and to the management of wilderness. The keys to maximizing value lie in analyzing the information needs of individual areas, promoting the use of wilderness for biological research, and increasing commitment for the basic inventory and monitoring needed to meet even the most fundamental wilderness goals.

RESEARCH ON SOIL AND VEGETATION IMPACTS

Across the wilderness system as a whole, the agents of change associated with human activities that have most affected natural vegetation and soil conditions are probably fire and grazing of domestic livestock. The effects of fire suppression, including longer intervals between fires, buildup of fuels, and unusually large catastrophic fires, are expressed across vast wilderness acreages. Future attempts to return fire to a more natural role, either through allowing selected fires to burn or through scheduled ignitions, will also affect vast acreages. Research into the natural role of fire, its effects, and its management has been one of the most active fields in wilderness research. Refer to the review paper presented in this conference by Bruce Kilgore for more detail.

Although not well documented, impacts of domestic grazing animals, particularly cattle and sheep, have been pronounced in many wildernesses, particularly in the West (Vale 1977; Vankat and Major 1978). Many areas supported huge herds of animals during the late 19th and early 20th centuries. Although herds were cut back dramatically following recognition of unacceptable levels of deterioration, livestock grazing still occurs in over 40 percent of wildernesses (Washburne and Cole 1983).

Literature on the relationship between domestic livestock grazing, vegetation, and soils is extensive. Most of it is prescriptive, however, and little of it applies directly to wilderness. Descriptions of grazing effects on natural vegetation have been of secondary importance, although they do exist—even for wilderness areas (Reid and others 1980). With few exceptions, range management studies have had objectives of maximizing sustained production, with little regard for the "naturalness" of conditions. Wilderness management could be aided greatly by the development of management prescriptions that optimize both production and "naturalness." Managers of about one-quarter of the wildernesses with grazing feel it is a problem; most of these areas are located in the Southwest (Washburne and Cole 1983). This is a major research gap.

A unique opportunity to study grazing in wilderness settings was provided in 1982 when, as part of a bill to prolong grazing in Capitol Reef National Park, Congress directed the National Academy of Sciences to study grazing and its impacts at Capitol Reef (Public Law 97-341). A select committee of eminent scientists, after reviewing the situation in the field, talking with concerned parties, and examining available literature, proposed a research program. To do the job correctly, they estimated a budget of $930,000, to be provided by the National Park Service. The proposal has been shelved. The interesting thing about this example is that it provides an objective measure of the level of funding necessary to research this subject. Examples of what it would cost to conduct wilderness research correctly (as opposed to how much funding is available) are almost as rare as funding for such projects.

Air pollution has also affected the vegetation and soils of wilderness areas. For example, ozone effects on vegetation, including increased mortality of ponderosa pine, have been documented in the San Bernardino Mountains of southern California (Cobb and Stark 1970), where several National Forest wildernesses are located. "Acid rain" effects on forests similar to those in many northeastern wildernesses are currently the subject of considerable research. Baseline data, to monitor future effects of air pollution, are being collected in other areas, from Sequoia/Kings Canyon National Parks in the West to the Shenandoah and Great Smoky Mountains National Parks in the East. Refer to the review paper presented in this conference by Kent Schreiber and James Newman for more detail on air quality and its management.

The effects of introduced animals on vegetation have been an active subject of research, but almost entirely in the National Parks. For example, 20 papers (about 5 percent of those presented) at the Second Conference on Scientific Research in the National Parks were on introduced animals, their effects, and their management. Considerable attention has been focused on European wild boars in the East, feral pigs in Hawaii, burros in the Southwest, and nonnative mountain goats in the Olympics. In several cases, such as burros in Grand Canyon, this research has led to aggressive control measures. Conceivably much of the knowledge generated from these studies can be applied to wilderness managed by other agencies, but with no comparable research program.

Although less studied in wilderness, vegetation change has also resulted from the introduction of plants, such as salt cedar in riparian areas of the Southwest (Robinson 1965), and of diseases or insect pests, such as Dutch elm disease (Karnosky 1979) and the gypsy moth (Marshall 1981). Elimination of species, such as large predators, has also affected the biota, although again these effects are not well documented. Wilderness management can probably benefit from active research programs, particularly related to insects and disease, outside wilderness.

A final controversial source of change is mining. Only about one-third of all wildernesses have mining claims or developments (Washburne and Cole 1983), and effects on vegetation and soil where mining does occur are likely to be highly localized. Transportation systems may be more disruptive than the mining itself, although improper disposal of tailings can have widespread effects. Much research, outside wilderness, has been directed at minimizing and rehabilitating impact. However, important constraints in wilderness that make direct application of nonwilderness research problematic include the importance of "natural conditions," the lack of mechanized equipment, and the prevalence of extreme environmental conditions that make regeneration more difficult. Research analogous to that being done outside wilderness, particularly on methods for rehabilitating mining disturbances, could be extremely helpful to wilderness management.

Of the significant causes of impact on vegetation and soils, the cause with at least a modestly developed research base that is not being dealt with elsewhere at this conference is recreation. Recreational impacts are a significant problem, at least locally, in most wildernesses. They are more subject to management control than air pollution, for example, and they are the subject of a discrete discipline—recreational ecology. This discipline—its development, its methodologies, the results it has provided, its application, and its future—will be the focus of the rest of this paper.

DEVELOPMENT OF RECREATIONAL ECOLOGY RESEARCH

Beginnings

The field of recreational ecology is now over 50 years old. The earliest study I could find was an examination of recreational impacts on the California Redwood State Parks (Meinecke 1928). Similar nonrigorous descriptions of impact in recreation areas typified the state of the field, particularly in the United States, until the mid-1960's. Most of this work was conducted in the National Parks; examples include the documentation of packstock impacts in Sequoia and Kings Canyon National Parks by a series of researchers from Armstrong (1942) to Sumner (1968), of subalpine meadow damage at Mount Rainier (Brockman 1959), and of impact problems in Grand Teton National Park (Laing 1961; Merkle 1963).

During this same period of time, academic interest in the ecological effects of recreation developed. Lutz (1945) studied soil changes on picnic sites in Connecticut. Several theses—Thornburgh's (1962) study of soil compaction and vegetation change on backcountry sites in Mount Rainier National Park and what is now Glacier Peak Wilderness, Hartesveldt's (1963) study of soil compaction and growth of giant sequoia in Yosemite National Park, Willard's (1963) study of recreational impacts on alpine tundra in Rocky Mountain National Park, and Wagar's (1964) treatise on carrying capacity—were also completed. These studies were more rigorous and quantitative; they provided estimates of amount of change by comparing recreation sites with controls. They also employed a wider variety of measurement techniques. This set the stage for efforts to more thoroughly describe the nature and significance of recreational impacts. It is worth noting that these studies examined a wide range of situations along the recreational spectrum from heavily used roaded parks and picnic areas to remote campsites in wilderness.

Europeans were taking a somewhat different tack at this time. In England, particularly, most concern was with the impact of informal countryside recreation—strolling and picnicking in a rural setting. Compared with the United States, use levels were high but not as highly concentrated at such destination sites as designated picnic grounds or campsites. This difference may explain why early European recreational ecology studies were less likely to be descriptions of conditions on recreation sites. Instead they tended to focus on the effects of a more generic activity—trampling. This focus on activity, as opposed to site conditions, placed more emphasis on process and may explain why the Europeans moved more rapidly into the experimental phase of impact study.

Pioneering work along these lines was done by Bates (1935), in England. He described the conspicuous vegetational gradient perpendicular to trails—from bare earth, through a short vegetation of trampling-resistant species, to natural vegetation—noting that changes in species composition reflected differential tolerance both to direct mechanical injury of vegetation and to the indirect effects of soil change. His greatest contribution was probably his use of experimentation to examine the relative importance of these two mechanisms of change. Although none of the European literature deals with situations analogous to wilderness or backcountry, much of it contributes to our understanding of wilderness impacts due to this emphasis on the effects of trampling.

Early Development

These beginnings served to define the magnitude of the problem and outline many of the components in need of examination. This led to a period of time during the 1960's and early 1970's when research in recreational ecology, supported almost entirely by governmental agencies charged with managing recreational and natural areas, intensified. Early in the 1960's the most noticeable developments were in the United States. Developed campsite conditions and management were studied by a number of Forest Service researchers—Magill and Nord (1963) in California, Wagar (1965) and his associates in the Intermountain West, Ripley (1962) in the southern Appalachians, and LaPage (1962) in the Northeast. Cooperators at the University of Minnesota began a series of projects examining wilderness campsites in the Boundary Waters Canoe Area (Frissell and Duncan 1965). The National Park Service also sponsored a study of conditions on developed campsites in Rocky Mountain National Park (Dotzenko and others 1967) and how damaged sites can be rehabilitated (Jollif 1969).

These studies improved knowledge in three general areas: (1) the importance of factors that influence amount of impact, such as amount of use or environmental conditions (LaPage 1962; Ripley 1962; Wagar 1964; Frissell and Duncan 1965; Dotzenko and others 1967; McCool and others 1969); (2) change in campsite conditions over time (LaPage 1967; Magill 1970; Echelberger 1971; Merriam and others 1973); and (3) methods for improving vegetation conditions on deteriorated campsites (Jollif 1969; Cordell and James 1971; Beardsley and Wagar 1971; Cordell and others 1974; Beardsley and others 1974).

In Europe, research activity intensified in the late 1960's. Two conferences in 1967, one sponsored by Great Britain's Nature Conservancy (Duffey 1967), the other by the International Union for the Conservation of Nature and Natural Resources (1967), focused attention on the ecological effects of recreation. Two active centers of research were the Nature Conservancy's work on problems resulting from new ski developments on Scottish mountain tundra (Watson and others 1970; Bayfield 1971, 1973, 1979) and the work of Conservation Course students from University College, London (Speight 1966; Goldsmith and others 1970; Burden and Randerson 1972).

These studies were notable in their attempt to interject more rigor and quantification into recreational ecology. More elaborate experimental designs and techniques were developed, and there were some early attempts to use multivariate statistics. Liddle and Greig-Smith (1975), studying the effects of trampling on sand dune vegetation in Wales, followed in this tradition. They utilized experimentally controlled applications of trampling to develop mathematical models relating amount of trampling to consequent effects. On campsites in northern Michigan, Legg (1973) developed multiple regression equations that predicted level of impact on the basis of site factors—an extension of analytical techniques first used by Wagar (1964).

Another subject that received some work in the early 1970's was trail deterioration and its management. The vegetation on and along trails had been examined as early as Bates' (1935) study but primarily to better understand the effects of trampling. Ketchledge and Leonard (1970) provided an early estimate of erosion rates on trails in the Adirondack Mountains. More rigorous studies followed. Root and Knapik (1972) and Bayfield (1973), working in the Canadian Rockies and the Scottish Highlands, respectively, studied the relationship between trail condition and various site and design factors. Dale and Weaver (1974) looked at the relationship between trail width and depth and amount of use, whether use was by hikers only or horses and hikers, and whether the trail was located in meadow or forest.

Another research program that should be mentioned here is the series of studies undertaken between 1972 and 1975 by Parks Canada in the Canadian Rockies (for example, Landals and Knapik 1972; Landals and Scotter 1974). These reports were general assessments of impact problems, particularly on campsites and along trails, with recommendations for management. Although study methods generally lacked rigor and the reports were never published, this set of reports probably represents the most thorough assessment of impacts and their management available anywhere.

By the mid-1970's, then, the focuses of research concern had been established and a sizable quantity of research data had accumulated. The basic research questions being addressed were (1) what changes occur on campsites/picnic sites? (2) what changes occur on trails? (3) what changes result from trampling? (4) how do site conditions change over time? (5) how do impacts relate to use and environmental factors? and (6) how effective are certain management techniques at avoiding or rehabilitating impact? The first syntheses of the recreational ecology field also were compiled (Speight 1973; Goldsmith 1974; Liddle 1975a). With recreational use and consequent impact problems increasing greatly every year, it appeared that the field of recreational ecology was ripe for moving from its largely descriptive and uncoordinated adolescence into a more rigorous, focused, mature phase.

Recent Development

When we look at research activity in terms of number of publications, the late 1970's appear to be a "golden age" for recreation ecology. The total number of publications in the late 1970's was twice that of the early 1970's (fig. 2). However, this number was inflated by several conferences—two on scientific research in the National Parks and one on recreational impacts on wildlands. These three conferences generated almost one-third of the published papers in this period, and the vast majority of these papers offered only modified versions of data published elsewhere.

By the early 1970's, the Forest Service had terminated all of its earlier recreational ecology research programs. In fact, between the early 1970's and 1980, I could find

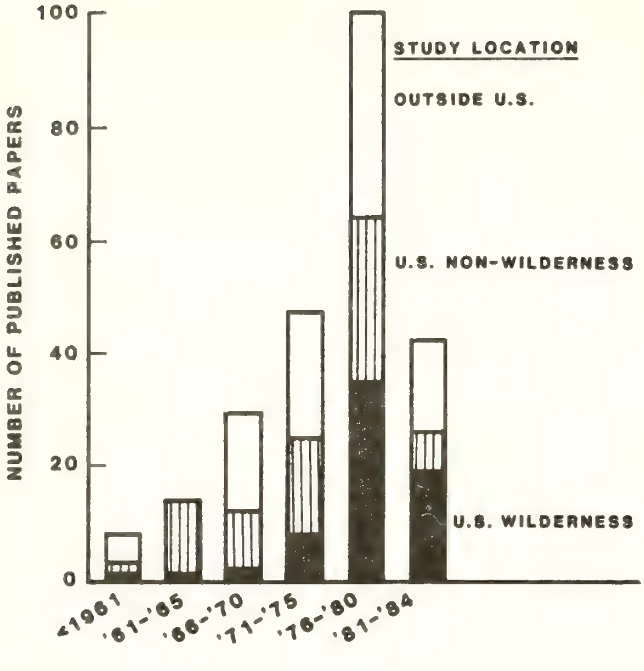


Figure 2.—Number of recreation ecology publications from various time periods. Papers in conference proceedings were considered publications, but theses were not.

published results from only two studies supported by the Forest Service—Helgath's (1975) study of trail erosion in the Selway-Bitterroot and Fay's (1975) test of fencing, fertilization, and liming as possible means of restoring vegetation to a backcountry camp in New Hampshire's White Mountains. The only other relevant papers are a haphazard collection of non-data-based papers on measurement and management techniques (Hendee and others 1976; Fay and others 1977; Leonard and Whitney 1977; Rinehart and others 1978; Frissell 1978). Most of the early researchers were still in Forest Service recreation research, but their focus had shifted to the social and planning aspects of recreation.

In contrast to the Forest Service, the 1970's was a period of growth in this field for the National Park Service. During this period recreational ecology papers resulted from supported work in Grand Canyon (Carothers and Aitchison 1976), Yosemite (Holmes and Dobson 1976; Malin and Parker 1976; Hecht 1976; Foin 1977; Lemons 1979), Sequoia/Kings Canyon (Parsons and DeBenedetti 1979; Parsons and MacLeod 1980), Denali (Stelmock and Dean 1979), Olympic (Schreiner and Moorhead 1976), Mount Rainier (Edwards 1979), and Great Smoky Mountains (Bratton and others 1978, 1979) National Parks, and Ozark National Scenic Riverway (Marnell and others 1978). Although somewhat more rigorous than the anecdotal work of the 1960's and before, these projects were largely descriptive. Objectives were usually to survey impacts over large areas. Although often quantitative in nature, only the most obvious impacts were examined, and generally neither measurements nor analyses were very sophisticated. This primarily represented an expansion of the regional coverage of impact studies. This increased coverage was valuable from the standpoint of being able to evaluate the general applicability of specific results; however, it did little to advance methodology or theory or to move the field toward a deeper plane of inquiry or understanding.

In addition to an expansion of regional coverage, Park Service studies looked, at least briefly, at two new sources of impact—campfires (Fenn and others 1976) and urine (Holmes and Dobson 1976).

Many of the papers published in the late 1970's were short-term, one-time studies by academics (for example, Hartley 1976; Coombs 1976; Jones 1978; Rutherford and Scott 1979). Presumably, students interested in the subject conducted these studies, with the assistance of a professor who found the subject an interesting change, and then both went on to do something else. New places were studied and new information was uncovered, but there was no building, coordination, or deepening of the field.

Many countries were involved in recreation ecology research by the late 1970's. Work continued in Great Britain but at a much reduced rate. Recreation ecology research was also done in Finland (Kellomäki 1977), the Netherlands (Boomsma and van der Ploeg 1976), Poland (Falínski 1975), Sweden (Byran 1977; Emanuelsson 1979), the U.S.S.R. (Rogova 1976; Kazanskaya 1977; Spiridinov 1979), Australia (Edwards 1977), and Canada (James and others 1979).

Generally reviewing the 1970's, we see expansion in the field of recreation ecology. Scientists from more countries were studying recreational impacts. Within the United States, increased interest on the part of the Park Service partially offset the demise of Forest Service research programs. All major lines of inquiry were advanced, and new ones, particularly the development and evaluation of management techniques and monitoring systems, appeared. The major problem was lack of continuity. The field remained dominated by short-term, one-of-a-kind studies that did not build on each other.

CURRENT STATE OF THE DISCIPLINE

In the 1980's, as managers of more and more wildernesses are struggling to deal with recreational impact problems, we would like to think that this field of inquiry is continuing to mature. Unfortunately, there is much to suggest that this is not the case. Productivity has dropped radically; from an average of 20 papers per year in the late 1970's, the rate in the early 1980's has dropped to 10 per year. Participation has dropped even more radically; of 44 papers I could find that have been published since 1980, 18 are by just two authors.

Within the Forest Service, currently about 20 professional scientists are doing recreation research. None of these researchers emphasize recreational ecology. Reviewing Forest Service recreation research publications between 1961 and 1982, I found only 33 out of 932 references (3.5 percent) dealing with recreation impacts and their management. This compares with 100 on visual resource management, 94 on user descriptions, preferences, and benefits, and 62 on how to assess use. The Forest Service does support recreational ecology research by outside cooperators; however, such research has been conducted in only five wilderness or backcountry areas.

A similar situation exists in the Park Service, although here the emphasis is on basic biology rather than social research. Of the papers presented at the Second Conference on Scientific Research in the National Parks in 1979, 5 percent dealt with impacts of recreation on the natural environment. This compared with 5 percent for water, 5 percent for air, 12 percent for social recreation research, 13 percent for fire, and over 50 percent for basic biology.

It is more difficult to assess participation outside these agencies. No one in the U.S. Department of the Interior, Fish and Wildlife Service or Bureau of Land Management appears to be doing recreation impact research. Moreover, research by the academic community is sporadic at best. I could find only 50 authors (or groups of authors) who have reported—in published or unpublished form—data-based research on recreation impacts in wilderness/backcountry settings. Only 10 of these 50 participated in more than one study.

This limited participation would be understandable if ecological impacts and their management were not a problem. However, this is clearly not the case. We conducted a survey of managers of all existing wildernesses and many likely additions to the wilderness system in 1980 (Washburne and Cole 1983). Our results corroborated those of an earlier sample of 35 wilderness managers (Godin and Leonard 1979), finding that recreational impacts, particularly on trails and campsites, were the most common wilderness management problem in the eyes of managers.

Outside the United States, the condition of the discipline is as bad—if not worse. Activity in the 1980's is less than at any time since the early 1960's. In 1983, I attended a conference on the ecological impacts of outdoor recreation in Europe and North America. Organized by the Recreation Ecology Research Group—a primarily British group that includes some of the first scientists to work in the field—the conference had the ambitious goal of bringing together most of the researchers in the field. From discussions with many of the attendees, it appears that only a couple of people in the world are currently able to pursue careers in recreational ecology research.

Perhaps the one bright point, from the perspective of this conference, is that a large proportion of the research in the 1980's has been in wilderness in the United States. Although recreational ecology is at its lowest ebb since the 1960's, more new studies in wilderness have been published since 1980 than in any other 5-year period. We now have published data on ecological impacts from nine National Forest wildernesses: Boundary Waters Canoe Area, Eagle Cap, Frank Church-River of No Return, Selway-Bitterroot, Lee Metcalf, Bob Marshall, Rattlesnake, Alpine Lakes, and Glacier Peak; from wilderness or backcountry in 13 National Park areas: Grand Canyon, Grand Teton, Great Smoky Mountains, Dinosaur, Mount Rainier, Denali, North Cascades, Olympic, Sequoia/Kings Canyon, Yosemite, Rocky Mountain, Guadalupe Mountain, and Ozark National Scenic Riverway; as well as from the Adirondack Mountains in New York, the Mission Mountains Tribal Wilderness in Montana, and the Green Mountains of Vermont (fig. 3).

Given that we now have about 90 million acres of wilderness, in over 450 different units, these 24 areas represent a meager start at even describing impact problems. The best represented parts of the system are, in order, the Boundary Waters Canoe Area (BWCA), the Northern Rockies, the Sierra Nevada, and the Pacific Northwest. Major gaps exist in the East, the Central States (except for the BWCA), the Southwest (except for the Sierra Nevada), and Alaska.

A problem that may be more significant than inadequate regional representation is the declining trend in research sophistication. An increasing proportion of papers are not based on data. There has been relatively little progress in the development of either theory or more sophisticated research techniques.

In a review of recreation ecology literature in Europe in 1976, Satchell and Marren stated:

> We found a great disparity between the relative abundance of data on recreational demand such as numbers, origins and attitudes of visitors, and the paucity of data on the ecological consequences of recreational activities . . . . We consider that the current level of research is not commensurate with the magnitude of the problem of reconciling the maintenance of amenity and conservation interest in areas used for public recreation with the demand for outdoor leisure pursuits in increasingly urban societies.

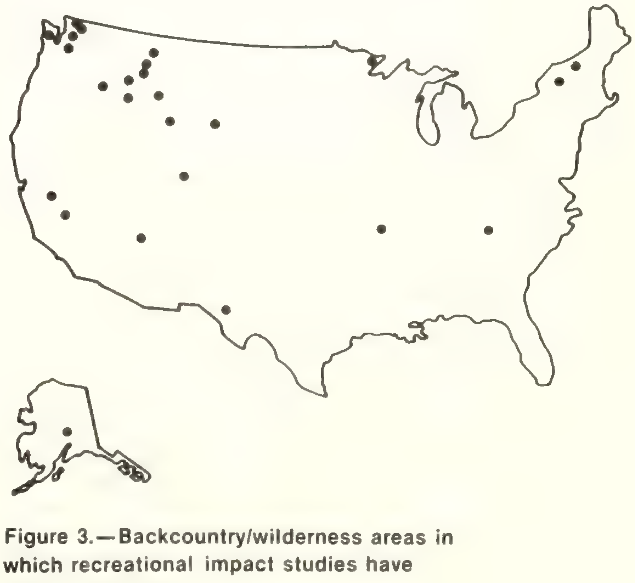


Figure 3.—Backcountry/wilderness areas in which recreational impact studies have been conducted.

Clearly these disparities are even worse a decade later—in Europe and in the United States.

In another review, Goldsmith (1974) wrote that most studies merely "record observations of a rather superficial nature and only a few describe specially designed experiments with detailed analysis of the resultant data." This situation has also not improved dramatically. Most research continues to merely document the obvious; time frames are short, theory is lacking, and few studies are comparable.

None of this is very surprising when a field is only the part-time interest of a few researchers. Even today there are essentially no careers available in recreational ecology. Only with the possibility of a career can we expect people to undertake the long-term work that is critically needed or to design complex studies that examine all the variables that influence impacts. Only then will studies build on one another or will students be able to get training in the field. Only then will it be possible to develop the critical mass necessary to stimulate creative thinking and the development of theory.

It has been suggested that the ecology of recreational impacts is known well enough and is seldom more than documentation of the obvious. This seems to me to be more an indictment of what the field has done than what it could do. Because support for this discipline has never solidified, the field is characterized by an ebb and flow of personalities all starting at a low level of sophistication and moving on to greener pastures before any significant advancement can occur.

RESEARCH METHODS

Study Designs

A variety of study designs have been utilized in recreational ecology studies. I choose to place them in four categories: descriptive surveys of recreation sites, comparisons of used and unused sites, before-and-after natural experiments, and before-and-after simulated experiments. Within each of these broad categories there can be tremendous variation in spatial and temporal scales, as well as the soil/vegetation parameters under study.

The simplest and, to date, the most common of these approaches is the descriptive survey of recreation sites (for example, Bratton and others 1978, 1979). Vegetation and soil parameters are measured or estimated to determine the current condition of the resource. Variability across an entire area can be assessed, and conditions can be compared to objectives to determine whether or not problems exist and management actions are required. Site conditions can be correlated with use and environmental conditions to suggest hypotheses of cause and effect. Conditions can also be followed over time to establish trends.

The two basic problems with this approach are that (1) there is no measure of impact or change and (2) it is difficult to evaluate cause and effect. Existing conditions are affected by a wide variety of environmental as well as use parameters. Fifty percent vegetation cover on a site may be perfectly natural, or it may represent a dramatic loss of cover. Without a comparison to undisturbed conditions, it is impossible to evaluate the effects of recreational use. Moreover, there is also the problem of very little information on what has actually happened to the sites under study. Recreational impact is variable from year to year, group to group, and site to site. Surveys of site condition, alone, are incapable of substantially improving our ability to predict the consequences of various types and amounts of use in various places.

The great value of these studies is in their immediate management utility. They can usually be completed relatively rapidly, without a high investment in training, and are useful in assessing the general condition of the resource and monitoring its change over time. Thus these studies can form the backbone of information needed to guide day-to-day management.

Another common research approach involves comparison of used and unused sites (for example, Cole 1982b). With this approach, ecological impact is estimated on the basis of a comparison between conditions on recreation sites and neighboring undisturbed sites (controls) with similar environmental settings. The implicit assumption is that the recreation site was similar to the control prior to use and, therefore, that any difference between the two sites is the result of recreational use. Once these estimates of change are obtained, it is a relatively simple matter to compare change on sites with different use and environmental characteristics—utilizing a cross-sectional design—in order to better understand how these affect amount and type of impact.

This is a very convenient and attractive approach because, in contrast to the previous approach, it does provide a measure of change. Moreover, changes—despite occurring over a long period of time—can be evaluated at one point in time; long study periods are not required.

However, two major sources of error exist that can make the results of this approach misleading. First, controls never perfectly replicate preexisting site conditions. Therefore some of the difference between recreation sites and controls is a result of environmental variability rather than recreational use. This problem becomes increasingly severe as local environmental variability and the uniqueness of sites selected for recreation use increase. In some situations it is also impossible to find controls that have not been affected by recreational use. Care in selecting controls and disqualifying sites without adequate controls will counter some of these problems. The environmental variability problem can be reduced with a large sample size, and its effect can be better interpreted with an evaluation of inherent variability between control sites.

Second, it is difficult to identify, let alone control, all the ecological and human-use variables that affect the amount of change occurring on a site. For example, a common objective is to assess the effects of amount of use on amount of impact. To do so requires accurate measures of use, which are seldom available. Even where current use can be assessed, there is little certainty that current use patterns reflect the past use history of the site. Moreover, the effect of amount of use is strongly modified by type of use, timing of use, and the resistance of the site—all of which are difficult to assess and virtually impossible to control perfectly.

The solution to these problems is not to abandon this approach; rather, the solution lies in controlling variability as much as possible, studying the influence of these other variables, sampling as many sites as feasible, not exceeding the limitations of data in the analysis phase, and qualifying the final results. For example, rather than treating 1 year's use data as interval level data and regressing it against some measure of impact, it is much more realistic to establish discontinuous classes of use and use analysis of variance (for example, Marion and Merriam 1985). The analysis may be less sophisticated, but the results are less likely to be misleading. Similarly, unless the magnitude of statistically significant differences is great, researchers would be prudent to recognize the importance of uncontrolled variability and play down the importance of these differences.

Most of these problems are more effectively dealt with by using the longitudinal before-and-after natural experiment approach (for example, Merriam and others 1973). In these studies, site conditions are measured before use of the site commences and then after it has occurred. Changes identified in this way are more accurate assessments of recreational impact because the error caused by assuming a site was identical to a control is eliminated. Ideally, conditions will be measured periodically and over a long enough period of time for the effects of recreational use to equilibrate. If this is not done, this approach loses value because it will not be possible to predict the consequences of long-term use, the primary objective of most research. It is also important to follow changes on control sites in order to incorporate nonrecreation-related changes into the final interpretation of results. Finally, it is imperative to accurately evaluate both amount and type of use on the site. If this is not done—and it is extremely difficult to do in backcountry—this approach loses many of its advantages over the cross-sectional approach previously discussed.

A variation on this approach is to evaluate the effects of a change in use or management or both by taking measurements before and after the change. Examples might include examining the effect of packstock on a trail that had never had stock use before or recovery on a campsite that was being closed to all use (for example, Stohlgren 1982). Such natural experiments can be enlightening. However, they need to be undertaken under a wide variety of situations before it will be possible to evaluate the general applicability of results.

To get beyond entirely site-specific conclusions, longitudinal studies need to utilize factorial designs. For example, the effect of amount of use on sites located in various environments could be evaluated by stratifying sites environmentally and examining sites receiving a wide range of use. However, this brings out the primary disadvantage of this research approach—its cost, both in terms of time and money. Sites need to be measured periodically, probably at least once per year (and preferably more frequently) for at least 5 years. Use measurements need to be taken continuously over this time period. In backcountry this requires a lot of field time. Moreover, results will not be in hand for a long period of time. Finally, it is often difficult to find the real-life situations needed for the factorial design or to even predict which sites will fall into which use category to ensure sufficient sample sizes in all cells of the factorial design.

The common solution to all of these problems is the simulated experimental approach (for example, Weaver and Dale 1978). The major difference between this and the preceding approach is that the investigator plans the application of recreational use. This makes it much easier to find the situations to be examined in a factorial experiment. It also makes use measurement easier and more accurate, and it makes it easier to eliminate variability in parameters not under study, such as whether trail use is by horse or hiker, or whether use occurs when soils are wet or dry. Occasionally, this approach has involved dropping an artificial "foot" or rolling a corrugated roller along the ground. More frequently, the investigators trample areas themselves, walking back and forth at known rates.

To be of most value, it is important to take measurements before and after each treatment. Changes also need to be followed on controls. Even where this is done, local environmental variability will interject some error into estimates of recreation-caused change because the effects of a given amount of use will vary with the tolerance different species have for impact. To predict the long-term consequences of continual use, it is best to both apply use and measure impacts over a period long enough for effects to equilibrate. This is costly and has never been done.

A major drawback to this approach is that it seldom truly simulates the type of recreation use of concern to managers. It is much more directly applicable to problems of trail deterioration and dispersed trampling than to campsite damage. It would be possible for investigators to camp different numbers of times on different vegetation types and measure responses. This would be very costly, however, and there are still variables, such as weather conditions, that cannot be controlled.

Each of these approaches, then, has inherent advantages and disadvantages. The more scientifically rigorous approaches are more costly and time-consuming and less likely to simulate "real" conditions. The other options have more error in their estimates of recreational impact and are less capable of unraveling cause and effect. All approaches can provide valuable information. The key is to match the approach to the objectives and situations at hand, while carefully designing a study that minimizes the problems inherent to any single approach. Finally, most light will be shed on the subject by utilizing several approaches simultaneously. For example, descriptive surveys can help managers assess their current situation and provide baseline data for a monitoring program. Cross-sectional studies, in a factorial design, can suggest what factors managers might want to manipulate to minimize impacts. Long-term simulated experiments can explore these hypotheses in more detail to "fine tune" future management, while longitudinal studies are useful for evaluating the effectiveness of new management policies taken to counteract problems identified in the descriptive surveys.

With few exceptions, recreational ecology studies have only examined obvious impacts and have operated at an intermediate level of resolution. There have been few detailed studies of the process whereby a change such as a shift in species composition occurs. Likewise there have been few studies of interrelationships between ecosystem components affected by recreational use. This neglect of both process and interrelationships at the ecosystem level makes it difficult to evaluate the significance of recreational impacts in anything other than esthetic terms.

Vegetation and Soil Parameters

When describing vegetation response to recreation, most attention has been given to description of the community and damage to trees. Descriptions of morphological and physiological responses are much less common. Vegetation is usually sampled along transects or in plots of varying size and configuration and then described in terms of percentage cover of total vegetation and each species. Many studies have used these data to characterize species composition, diversity, and life or growth form spectra. Fewer studies report frequency, density, or biomass. Population structure has been described, for *Juncus trifidus*, by Pryor (1985). Fletcher and Shaver (1983) studied plant demography of disturbed *Eriophorum vaginatum* populations.

In forested areas, investigators commonly report frequency of tree damage and root exposure and density of tree reproduction. A few also have reported diameter class distribution and have observed apparent declines in vigor and growth rates.

The most frequently reported morphological parameters are vegetation height, growth form, and bud location. Several studies have also reported number of flowers per plant. In perhaps the most indepth description of morphology, Liddle (1975a) reported data on leaflet area for *Trifolium repens* and on number of tillers per plant, length of live tillers, number of live leaves per tiller, dry weight per shoot, and dry weight per tiller for *Festuca rubra*. Goryshina (1983) presented data on leaf area and cell size and number for three forb and two moss species. He also described thallome thickness and size and number of algal cells and hyphae in two lichen species.

In keeping with the paucity of information on the impact process, there are very few data on physiological responses to use. The only physiological responses examined at all are seed production, germination and dissemination, seedling establishment, and changes in the carbohydrate content of roots. However, Blom (1976, 1977), who studied the effects of trampling and soil compaction on the emergence and establishment of four *Plantago* species, has shown the direction such studies could take if we wanted a more detailed understanding of the physiological basis for observed impacts on vegetation.

Descriptions of soil changes, if anything, have been even more superficial. Most studies report loss of organic horizons, usually as changes in the percentage cover of litter and/or exposed mineral soil. A few also report the depth of organic horizons. Considerable attention has been given to soil compaction, with investigators usually reporting either penetration resistance or bulk density of the soil. While bulk density has the advantage of not being subject to moisture conditions, penetration resistance is a more sensitive indicator of impact. Others have measured consequences of compaction, particularly changes in total porosity, pore size, and infiltration rates. There are also some data on moisture content, organic matter content, and evidence of erosion. Soil properties for which very limited data exist include pH, nutrient content, texture, aggregate stability, and soil biota.

A few studies have attempted to model recreational effects on erosional processes utilizing the Universal Soil Loss Equation (Kuss and Morgan 1980, 1984; Morgan 1985). Such theoretical work has potential, but has yet to be translated into practical application.

As with the evolution of the recreational ecology discipline as a whole and the development of theoretical structure, research methods have not advanced greatly since Bates' (1935) early work on trampling effects on vegetation. Experimental work is receiving more emphasis but is not fundamentally different from earlier work. Similarly, more advanced techniques and equipment are available for measuring soil and vegetation properties but are seldom used.

RESEARCH RESULTS

Over the more than 50 years of research on recreational impacts, a considerable body of information has developed. Much of it is highly site-specific, but many general conclusions can be drawn from this work. I will begin by discussing descriptive studies of the effects of recreational activities on different types of recreation sites and the spatial and temporal patterns these impacts exhibit. Following these, I will examine the factors that influence type and magnitude of impact and studies that evaluate the effectiveness of management techniques. I will conclude with a discussion of work on monitoring and site rehabilitation techniques. Research in wilderness will be emphasized, but I will draw on information gleaned from studies undertaken in more developed settings. Other syntheses of research results include Speight (1973), Liddle (1975a), Satchell and Marren (1976), Wall and Wright (1977), Manning (1979), Hart (1982), Kuss and others (1985), Price (1985), and Cole (1985a).

Descriptive Studies of Recreational Impacts

The three primary activities by which recreationists alter wilderness soil and vegetation conditions are (1) trampling by humans and packstock, (2) the collection and burning of wood in campfires, and (3) the confinement and grazing of recreational stock.

Before turning to a detailed discussion of the impacts associated with these three activities, several unstudied sources of change should be mentioned. The first of these is change caused by formal construction of campsites and trails. Campsite construction by managing agencies is rare but does occur. Generally this involves brush and tree removal and leveling of the ground surface. Trail construction, however, is common and probably has a greater effect on vegetation and soils than use of the trail by recreationists. During construction, vegetation is removed, soil is compacted, drainage is altered, and topography is rearranged.

Another unstudied source of change is the transportation of foreign substances into the wilderness. The propagules of exotic plant species are often brought unwittingly into the wilderness—on or in humans and packstock. Once inside they frequently establish themselves in disturbed areas. Garbage, soap, and waste water, particularly when scattered around campsites, can affect soil chemistry and biota; effects are likely to be highly localized, however. Finally, the effects of urinating on plants were investigated in Yosemite. This study concluded that although urine can lead to desiccation of plant tissues and increase the likelihood that a plant will be eaten, such effects are not pervasive enough to be significant (Holmes and Dobson 1976).

Effects of Trampling.—The most obvious effect of trampling is injury and destruction of ground-level vegetation. Injury results in reduced vigor and reproductive capacity in most species. At high levels of trampling or when fragile species are trampled, all plants may be eliminated. Some species may increase in abundance, however, and new species may be introduced. Increases are more likely to reflect reduced competition or a change in microhabitat than a positive response to trampling impact. For example, Pryor (1985) found that moderate levels of trampling increased the abundance of small *Juncus trifidus* plants, a species that germinates frequently on the bare and gravel surfaces that expand as a result of trampling. The final and most frequently documented results of trampling are loss of cover, reduction in stature, and shift in species composition.

The precise effects of trampling on plant morphology and physiology are poorly understood, as are the reasons some plants tolerate trampling better than others. Trampling reduces the area of individual leaves (Liddle 1975a). Goryshina (1983) demonstrated that this results more from inhibition of cell division than of cell elongation. Number of leaves and tillers, in grasses, is little affected by trampling (Liddle 1975a); however, number of leaves per shoot is reduced in orchids (Bratton 1985). Height is reduced and prostrate branching tends to increase as a result of frequent damage to terminal buds. Reduced height and leaf area decrease photosynthetic area; this depletes carbohydrate reserves (Hartley 1976) and can affect plant vigor. Physiological stress, such as reduction in photosynthetic area and carbohydrate reserves, along with mechanical damage to elevated buds, may explain reductions in flower density and seed production per flower (Liddle 1975a; Hartley 1976; Bratton 1985). However, few relevant studies have been conducted; this makes it difficult to evaluate whether these results are generally applicable or only apply to the species under study.

Trampling also compacts soils. Compaction reduces porosity, particularly the volume of macropores. This tends to reduce water-holding capacity in fine-textured soils and increase it in coarse-textured soils. Infiltration rates are universally reduced, leading to increased runoff and erosion potential. Other likely consequences that have only been studied in an agricultural context include oxygen shortages and changes in soil biota. Because these processes have never been studied in detail, we do not know with any surety what it is about compacted soils that makes vegetation reestablishment so difficult.

Many of these effects on soil are exacerbated by the abrasion and loss of organic horizons, a loss that becomes particularly pronounced following a reduction in vegetation cover. Loss of organic matter increases susceptibility to compaction and results in increased runoff. The soil biota is likely to be affected further, as is the germination capacity of species that prefer organic seedbeds. There is conflicting evidence regarding trampling's effect on organic matter incorporated within the mineral soil. Young and Gilmore (1976), Legg and Schneider (1977), Monti and Mackintosh (1979), Cole (1982b), and Marion (1984) found increases in soil organic matter content on campsites, while Dotzenko and others (1967), Dawson and others (1978), Rutherford and Scott (1979), and Stohlgren (1982) found decreases. This discrepancy does not appear to correlate with differences in vegetation, soil, climate, campsite age, amount of use, or measurement technique.

All of these changes are likely to affect germination, establishment, growth, and reproduction of plants. Compaction reduces the heterogeneity of soils and, therefore, the density of favorable germination sites (Harper and others 1965). Compaction increases the mechanical resistance of the soil to root penetration. This can reduce emergence of seedlings, although in some dry soils and for some species, this adverse impact is less important than the beneficial effect of increased water availability in compacted soils (Blom 1976). Once plants are established, low levels of compaction can lead to increased growth rates (Liddle 1975a). This probably reflects increased moisture again, and may not occur in soils where moisture is not limiting. At some level, compaction leads to oxygen shortage which, along with the mechanical resistance of the soil to penetration, inhibits root growth and, therefore, plant growth, vigor, and reproductive capacity. Effects on these processes are very poorly understood.

Impacts Associated with Campfires.—Ecologic impacts associated with campfires result from both the removal of wood, either dead or live, standing or on the ground, from large areas around campsites, and from the burning of this wood in campfires (Cole and Dalle-Molle 1982). Very little research has been conducted on this subject. The collection of firewood and associated trampling greatly enlarge the area affected by camping. In Great Smoky Mountains National Park, the area disturbed by firewood collection was typically more than nine times the size of the devegetated area around campsites. In this much larger area, number of live and dead trees, particularly those in smaller size classes, and woody fuels were reduced (Bratton and others 1982). Shifts in understory species composition—presumably a result of trampling—were also evident in areas disturbed primarily by firewood collection (Saunders 1979). In Grand Canyon National Park, where campfires are prohibited, the areal extent of disturbance around campsites is remarkably small given the heavy use many of these sites receive (Cole 1985b).

The significance of firewood collection to the entire ecosystem can only be suggested from studies undertaken outside the recreational context. Such studies suggest that the most serious impacts are likely to occur when woody debris larger than about 3 inches in diameter is removed. Decaying wood of this size plays an important and irreplaceable role in the ecosystem—in water and nutrient conservation and as a substrate for biological activity (Harvey and others 1979). Collection of wood that can be broken by hand is likely to have relatively little effect (Cole and Dalle-Molle 1982).

The effects of campfires are particularly severe for the areas actually burned. In one experiment, a single intense campfire eliminated 90 percent of the organic matter in the upper inch of soil (Fenn and others 1976). Fires are also known to lead to losses of certain chemical elements (nitrogen, sulfur, and phosphorus, for example), increases in pH and many cations, and decreases in moisture-holding capacity, infiltration rates, and mycorrhizal populations in the soil (Cole and Dalle-Molle 1982). However, such changes have never been studied in a recreational context. Significance has never been assessed in terms of effects throughout the ecosystem or difficulty of rehabilitating fire sites. Usually campfire impacts are highly localized, but where fire sites move around, continually being rebuilt after being removed by rangers or other campers, a sizable area can be affected.

Generally, the whole subject of campfire-associated impacts and their management has been neglected and is poorly understood. This is particularly unfortunate given the energy currently expended on educating people in proper use of campfires. Managers are developing educational messages, and social researchers are experimenting with delivery systems for these messages. And yet, the bottom line is that we have not studied the problem and its potential solutions enough to know what the message should be and how it should be tailored to different environmental and use situations.

Effects of Confining and Grazing Recreational Stock.—Recreational stock trample vegetation and soil, as hikers do. They also cause some unique types of impact resulting from their need to graze (unless grazing is prohibited and all feed is carried in) and to be confined when not in use. The primary effect of confinement is localized severe trampling damage. Because a primary means of confinement is tying stock to trees, other serious problems are root exposure, as soil is eroded from around the base of trees, and damage of tree trunks from the abrasive action of rope. Where stock are tied to small trees, girdling can kill the trees. In the Bob Marshall Wilderness, campsites frequented by parties with packstock have an average of 25 trees with exposed roots (Cole 1983a). Although this type of damage has not been well studied, the problem, its cause, and its solution are obvious; consequently, this is not a high research priority.

In contrast, the effects of recreational grazing—also not well studied—are subtle and complex, as are the pros and cons of various potential solutions. Most of what we know about grazing impact comes from range management studies outside wilderness, usually dealing with animals other than horses and mules and with management objectives that place little importance on natural conditions. Moreover, in the few studies of range condition that have been conducted in wilderness, it has not been possible to isolate the effect of recreational grazing because it is superimposed on the effects of earlier or, in many cases, ongoing grazing by domestic livestock.

Sequoia/Kings Canyon National Parks are the only wildernesses where the effects of recreational stock on meadows have been assessed in detail. Over 40 years of research have been conducted, from early qualitative surveys of meadow conditions (such as Armstrong 1942) to recent controlled clipping experiments. These studies have provided a basic understanding of the nature of problems, trends, and relationships between meadow conditions and important environmental and use variables. The payoff to management is a proposed stock management plan that is efficient (meaning management objectives are met without the imposition of unnecessary restrictions) and thorough (DeBenedetti and Parsons 1983). Implementation of the plan is currently stalled due to objections from some of the recreational stock users.

Early meadow surveys in the Parks identified problems of reduced vegetation cover, rill, channel, and gully erosion, and invasion of meadows by lodgepole pine and other "weedy" species. Trend studies showed that actions taken to deal with these problems, including closing certain areas to grazing and limiting numbers of animals and lengths of stay, were generally successful. However, more subtle changes, not readily identifiable in the early qualitative surveys, were occurring, and management success varied from place to place and year to year. Consequently, more intensive quantitative research was conducted in the 1970's. This research provided a better understanding of annual fluctuations in the productivity of major plant associations and identified the response of each association to different levels of herbage removal. A predictive index of susceptibility to trampling under different moisture conditions was produced for each association. This allows managers to predict the consequences of alternative use prescriptions for individual forage areas, even accounting for differing hydrologic years. In addition to managing use effectively, the plan also incorporates a monitoring plan and designates a network of representative meadows for each major association to be protected from stock use (DeBenedetti and Parsons 1983). Other areas would do well to emulate such a research and management program rather than ignore the problem or institute arbitrary actions not based on an understanding of the resource, its condition, and its variability.

Impacts on Campsites.—Although affected by some of the same activities, impacts on trails and campsites—the two major focuses of impact and management—are sufficiently different to be discussed separately.

Impacts on campsites result from trampling by humans and, sometimes, by stock; the collection and burning of firewood; the confinement and grazing of stock; pollution with garbage, soap, and other substances; and thoughtless or malicious acts, such as hacking trees. Of these, trampling is the only unavoidable activity. The others are optional, and effects can be eliminated through education or prohibition of activities. Trampling impacts and their management are more subtle and complex and will be covered in more detail here.

Currently we have research data on campsites from 15 wilderness/backcountry areas: Olympic National Park (Schreiner and Moorhead 1979), Eagle Cap Wilderness (Cole 1981a, 1982b), Sequoia/Kings Canyon National Parks (Dykema 1971; Simon 1978; Parsons and DeBenedetti 1979; Stohlgren 1982), Bob Marshall Wilderness (Cole 1983a), Lee Metcalf Wilderness (Frissell 1973), Mission Mountains Tribal and Rattlesnake Wildernesses (Fichtler 1980; Cole and Fichtler 1983), Selway-Bitterroot Wilderness (Ranz 1979; Cole and Ranz 1983), Frank Church-River of No Return Wilderness (Coombs 1976), Dinosaur National Monument (Jerry 1977), Grand Canyon National Park (Carothers and Aitchison 1976; Cole 1985b), Boundary Waters Canoe Area (Frissell and Duncan 1965; McCool and others 1969; Merriam and others 1973; Marion 1984), Ozark National Scenic Riverways (Sutton 1976; Marnell and others 1978), the Adirondacks (Rechlin 1973), and Great Smoky Mountains National Park (Bratton and others 1978, 1982; Saunders 1979).

Half of these are descriptive studies of campsite conditions without relation to controls. They portray the extent and distribution of campsites in varying condition, but do not describe what has happened to the sites in terms of recreational impact. Of those that did estimate amount of impact, this amount is related to amount of use by Frissell and Duncan (1965), Sutton (1976), Coombs (1976), Simon (1978), Fichtler (1980), Cole (1982b, 1985b), Cole and Fichtler (1983), and Marion (1984); to type of use by Cole (1983a); to age of the campsite by Marion (1984); to environment by Dykema (1971), Sutton (1976), and Cole (1985b); and to time since the campsite was closed to use by Parsons and DeBenedetti (1979), Ranz (1979), Cole and Ranz (1983), and Stohlgren (1982).

These studies universally report the loss of vegetation cover and species change that generally result from trampling. Differences in the magnitude of change reported often reflect incomparable study methods as much as real differences. Species change and cover loss are most pronounced close to the center of campsites. Stohlgren (1982), for example, found that the core area of campsites just closed to use in Sequoia National Park had lost over 90 percent cover (in comparison to controls), compared to about 40 percent loss on less used parts of the site away from the core. Species richness and vegetation height were also reduced more in the core than on the fringes of the site. The sharpness of this intrasite disturbance gradient and the magnitude of differences vary with both amount of use and environment. In the Grand Canyon, no vegetation survives in the core of all but the most lightly used campsites; however, the area immediately adjacent to this barren core typically loses only about 12 percent cover (Cole 1985b). When intrasite variability is disregarded, reported measures of cover loss on the entire campsite range from 96 percent in Eagle Cap spruce forests in Oregon to less than 20 percent on montane grasslands in Montana's Bob Marshall (Cole 1981a, 1983a).

Shifts in species composition have been pronounced in all but two cases—the Grand Canyon and Rattlesnake Wilderness (Cole and Fichtler 1983; Cole 1985b). In these two cases, an index of floristic difference between campsites and controls had a mean of only 31 percent and 27 percent, respectively, within the range of variability expected in undisturbed vegetation. This compares with a mean index value as high as 88 percent in the Boundary Waters Canoe Area (Marion 1984). Species change is highest when resistance of the natural vegetation is low and there are many trampling-resistant invaders to take the place of the original occupants. Close to 20 percent of the species found on Boundary Waters campsites were nonnatives.

All studies—with the exception of the Grand Canyon, where no change in composition occurred (Cole 1985b)—have found that grasses and sedges increase in relative importance on campsites. Although they too are damaged by use, they survive more frequently than other growth forms. Low shrubs are generally susceptible to damage, as are tree seedlings and lichens. Loss of tree seedlings has been nearly complete on most campsites studied and is an especially serious problem for the long-term maintenance of forested campsites. Large shrubs are relatively resistant to damage, particularly if they are widely spaced and thorny, as they are on Grand Canyon sites (Cole 1985b). Forbs and mosses are highly variable in response; as a group they are neither highly resistant nor highly susceptible.

Established trees, because of their size, are generally little disturbed by trampling. Even where the practice of tying horses to trees exposes roots, tree mortality is seldom a problem, unless girdling occurs. Some tree species do appear to grow less rapidly in trampled areas (LaPage 1962; Brown and others 1977; James and others 1979). In shallow soils trampling can also increase water stress (Settergren and Cole 1970) and lead to increased windthrow (Frissell and Duncan 1965).

Although large enough to be spared most trampling damage, trees on campsites are frequently felled and used for tent poles, hitchrails, and firewood. On campsites in the Eagle Cap and the Bob Marshall, the median percentages of trees that had been felled were 28 (four trees per campsite) and 15 (15 trees). This loss is in addition to trees with exposed roots—32 percent (three trees) in the Eagle Cap and 54 percent (28 trees) in the Bob Marshall (Cole 1982b, 1983a). Root exposure is even more prevalent in the Boundary Waters Canoe Area, where shallow soils aggravate the problem (Marion

1984). Further damage is inflicted pointlessly by jackknife artists and ax-wielders. Although most trees survive such injuries, thin-barked trees, such as aspen and paper birch, are often killed (Hinds 1976; Marion 1984). Typically, few trees on campsites show no evidence of damage. Moreover, tree damage, in contrast to trampling damage, is cumulative and even longer lasting.

Loss of organic horizons follows loss of vegetation. Many campsites lose vegetation without losing litter, but the reverse is seldom the case (Cole 1982c). Loss of organic horizons occurs as a result of both trampling and increased runoff and erosion. As with vegetation loss, litter loss is greatest around the center of the campsite. Stohlgren (1982) found litter loss, by weight, to be over 90 percent of control values in the core and just over 60 percent on the fringes. Reported estimates of decrease in the thickness of organic horizons for entire campsites range from 45 to 66 percent (Frissell and Duncan 1965; McCool and others 1969; Cole 1982b, 1983a; Marion 1984). Litter loss exposes more mineral soil and rock. Amount of increase is highly variable among campsites both within and between areas. Typical increases have ranged from 6 percent in the Mission Mountains (Fichtler 1980) to 59 percent in the Grand Canyon (Cole 1985b). Differences relate both to how much use sites receive and the thickness of organic horizons on undisturbed sites (Cole and Fichtler 1983; Marion and Merriam 1985).

As was mentioned earlier, there are conflicting results concerning soil organic matter on campsites. On backcountry sites in the Eagle Cap Wilderness and Boundary Waters Canoe Area, Cole (1982b) and Marion (1984) found increases of 20 and 17 percent, respectively. On campsites in Sequoia National Park, in contrast, Stohlgren (1982) reported decreases of almost 80 percent in the core and almost 50 percent on the fringes. In neighboring Kings Canyon National Park, Simon (1978) found increases at one lake and decreases at another. No adequate explanation for such discrepancies exists. Such differences may be important to any site rehabilitation attempt, although rehabilitation appears to be difficult under conditions of both soil organic matter accumulation and depletion.

Experiments have shown that impacts on mineral soil are initiated even before vegetation cover starts to decline (Quinn and others 1980). Increases in penetration resistance and bulk density—both measures of compaction—have been identified in most campsite studies. Bulk density increases of 0.1, 0.1, 0.3, 0.3, and over 1.0 g/cm^3 were found by Simon (1978), Cole (1982b, 1985b), Marion (1984), and Stohlgren (1982), respectively. Both Cole (1985b) and Stohlgren (1982) found increases in bulk density outside the campsite core to not be statistically significant. Increases in penetration resistance—a more sensitive indicator of compaction—are statistically significant beyond the campsite core, suggesting that some compaction occurs even if increases in bulk density are not substantial enough to be accurately measured. On campsite cores, increases in penetration resistance of as much as 214 percent (Marion 1984) and 337 percent (Cole 1985b) have been recorded.

Changes in porosity—one of the more significant effects of compaction—have also been investigated. In a developed campground in Ontario, Monti and Mackintosh (1979) found a 60 percent loss of macropores. Along with frequent surface crusting (documented by increases in penetration resistance), loss of macropores reduces infiltration rates. Although reductions in infiltration on campsite cores were only about 30 percent in the Eagle Cap Wilderness, they typically exceeded 70 percent in the Bob Marshall Wilderness and Grand Canyon National Park (Cole 1982b, 1983a, 1985b). Reductions in initial infiltration rates were slightly less dramatic than reductions in saturated rates. Beyond the core of campsites in Grand Canyon National Park, infiltration rates were not significantly slower than on controls (Cole 1985b).

Where studied, soil moisture content has been lower on campsites than on controls. Reductions in soil moisture were more pronounced on campsites in Sequoia than Grand Canyon National Park (Stohlgren 1982; Cole 1985b). Core areas had reductions of 65 percent and 38 percent of control values, respectively. Reductions in fringe areas were 23 percent and 8 percent. In Kings Canyon National Park, Simon (1978) found a reduction of 19 percent of control values. Campsites in the Boundary Waters Canoe Area had only 7 percent less soil moisture than controls. Lower soil moisture should be the general case, although Liddle and Greig-Smith (1975) showed that in dry sand-dune soils experimental trampling could increase both soil water content and the amount of water available to plants. Blom (1976) has shown that under these same conditions (dry sand-dune soils) more seedlings of *Plantago major* emerged when soils were compacted. So, although soil compaction can be detrimental, there are at least some circumstances under which it can be advantageous.

Finally, changes in the pH and nutrient content of soils have been investigated by Cole (1982b) and Stohlgren (1982). In both cases pH was higher on campsites, but the other results are remarkable in their inconsistency. Cole found a doubling in the concentrations of both Mg and Ca on campsites, while Stohlgren found these elements to be reduced by factors of more than two. Cole found no statistically significant differences, between campsites and controls, in concentrations of NO_3, K, and total N, while Stohlgren found sizable reductions in all of these. Cole also found an increase in Na and no change in PO_4, while Stohlgren found decreases in P and NH_4. Results of similar analyses on developed sites generally corroborate Cole's results. Most nutrients increase while others are unaffected; none are greatly depleted (Young and Gilmore 1976; Rutherford and Scott 1979). Although results are confused, I hesitate to suggest a need for research until the significance of such changes is demonstrated. Suggested reasons for increases in nutrients include scattering of fire remnants, soap, and litter around the site, as well as reduced leaching due to decreased infiltration rates.

Erosion—aside from what occurs around the base of trees that have had stock tied to them—is surprisingly unimportant. In Great Smoky Mountains National Park, for example, erosion is evident on less than 1 percent of the average area of intensive disturbance (Bratton and others 1978). Water velocities are low on most campsites because they are essentially flat, and soil does not detach readily from compacted surfaces. These factors inhibit erosion and compensate for the increase in erosion potential that results from reductions in vegetation cover, litter cover, and soil permeability on campsites. In most wildernesses, however, certain poorly located campsites likely will have serious erosion problems. Erosion problems are also unusually pronounced on campsites in the Boundary Waters Canoe Area, where soils are shallow and steep slopes from canoe landings to campsites are heavily trampled and eroded (Marion 1984).

Impacts on Trails.—It is more difficult to define when trail impacts become problems because the majority of change is purposeful change caused by trail construction and maintenance. Purposeful changes include opening up the tree and brush canopies in forest and shrublands; creating a barren, compacted trail tread that may alter drainage patterns; and producing a variety of new microhabitats—where slopes are flattened, rock faces are incised, and so on. Clearing vegetation increases light intensities and reduces competition for species capable of surviving along the trail. Shifts in species composition result from increases in trampling and grazing pressure, the dissemination of propagules of exotic plants, increases in nitrogen from urine and manure, increases in sunlight, and increases in moisture—less precipitation is intercepted by trees, fewer plants are losing water through evapotranspiration, and the compacted trail tread is shedding water along its sides.

The nature of shifts in species composition has been described, in wilderness situations, by Dale and Weaver (1974), Hartley (1976), Cole (1978), Stelmock and Dean (1979), and Teschner and others (1979). The most pronounced shifts are increases in exotic species and species with characteristics making them resistant to trampling, and decreases in shrubs and caulescent forbs. Meadow species often replace forest species (Dale and Weaver 1974). This reflects both a positive response to increased light along trails and the inability—according to general theory proposed by Grime (1979)—of plants adapted to the stresses of a low light environment to also adapt to a high disturbance environment. Specifically, shade-tolerant plants, in contrast to heliophytes, have more supportive and conductive tissue, greater leaf areas, and thinner cuticles, cell walls, and stems—morphological adaptations that make them susceptible to breakage (Cole 1979).

Where drainage disruptions cause water ponding, increases in moisture-loving plants and even aquatics occur. Where level, soil-covered trails are built across talus slopes, plants can spread into naturally inhospitable habitats. Numerous other construction effects on natural vegetation and soil conditions occur wherever trails cross the wilderness.

Because most of this is planned by management and accepted by the visitor, trail alteration becomes a serious problem only where it is unusually obtrusive (for example, where parallel ruts scar an alpine meadow) or where deterioration of the trail makes use difficult and requires the expenditure of large amounts of money and manpower for maintenance. While this is probably a realistic definition, it reflects the extent to which we use anthropocentric criteria to define impact problems. This anthropocentric bias is made even more clear by the fact that usually more money is spent dealing with trail problems than any other wilderness management problem.

Four important types of trail problems can be identified: (1) excessive erosion, (2) muddiness (with or without lateral spread), (3) multiple parallel trails, and (4) development of impromptu trails at attraction sites (for example, fishermen's trails around lakes or trailing and trampling damage near a waterfall). Erosion is a localized problem, although it does appear to be considerably more troublesome in the East, where trails are often steeper and use is heavier than in the West (Ketchledge and Leonard 1970; Bratton and others 1979). Two studies of erosion over an entire trail system (as opposed to examination of purposefully selected problem segments) found that deposition on trails actually exceeds erosion (Fish and others 1981; Cole 1983b). Material does move about, entering and leaving the system, but accumulation is greater than depletion.

As far as ease of use is concerned, the trail-system-wide lack of erosion is irrelevant. The problems are those stretches where erosion is pronounced, particularly where trails develop an uneven rocky tread or are deep and narrow. Interestingly, wide and deep trails (where erosion loss is greatest) are less of a problem to users than narrow and deep trails. Although trampling can cause erosion of some trails, its principal effect is to make the trail surface more susceptible to erosion by churning up the soil, reducing infiltration rates, and removing vegetation. The primary agent of erosion is running water from streams, snowmelt, intercepted springs, and even intense precipitation (Root and Knapik 1972). Erosion is primarily a problem where trails channel water and water is not diverted off the tread.

Erosion of wilderness trails has been studied by Ketchledge and Leonard (1970), Dale and Weaver (1974), Helgath (1975), Bratton and others (1979), Teschner and others (1979), Summer (1980), Fish and others (1981), and Cole (1983b). Most of these researchers studied the relationship between trail deterioration and use and environmental variables, a topic that I will discuss later. Dale and Weaver (1974), Bratton and others (1979), and Cole (1983b) also measured trail width, depth, and erosion problems, extremely site-specific data. Trails in Great Smoky Mountains National Park were generally wider and less deep than those examined in the Northern Rockies. In terms of annual change—again a very site-specific measure—Ketchledge and Leonard (1970) recorded an increase in trail width and depth of 1 inch per year in the Adirondacks. Summer (1980), working in Rocky Mountain National Park, found annual increases in depth of 0.4 to 5 inches (mean of 2 inches) and annual increases in width of 0 to 59 inches (mean of 5 inches). On two highly eroded segments in the Selway-Bitterroot Wilderness, Cole (1983b) recorded annual cross-sectional area losses of 30 and 56 in^2. Such figures represent the worst examples and are highly variable at all scales from a few feet to nationwide.

Muddiness can be a significant problem. In the Bob Marshall, where trails are often calf-deep in mud, complaints about damaged trails increased sixfold between 1970 and 1982 (Lucas 1985). Unwilling to walk through the quagmire, hikers and stock skirt the problem, widening the trail and the quagmire greatly. In some cases, mud is a temporary problem caused by snowmelt or by intense rainfall on trails that have been churned to dust. Mud can also be a season-long problem in soils with high or perched water tables (Helgath 1975). About 9 percent of the maintained trail system in Great Smoky Mountains National Park was muddy (defined as having a soil surface that moved when wet) (Bratton and others 1979). Surveying 17 miles of trail in the Selway-Bitterroot, Cole (1983b) recorded mud at 17 percent of the observation points, but only 1 percent of the trail was muddy enough to make travel difficult. The sporadic problem segments—28 in all—averaged 56 inches wide, almost 2.5 times the Forest Service maximum tread width standard of 24 inches.

Multiple parallel trails are a troublesome problem in meadows, particularly at high elevations. Here the problem is primarily esthetic, as such stretches are not difficult for hikers or stock to negotiate if they walk on one of the less deeply incised treads. This aggravates the multiple trailing problem further and leads to an increase in both the number of treads and the width of disturbance. From my observations, total width and intensity of surface deterioration never reach the extremes they do with muddiness problems. Multiple trailing has not been specifically studied in the United States wilderness. However, Price (1981) examined the problem in alpine meadows adjacent to the Sunshine ski area in Banff National Park, AB, and Palmer (1979) described some experiments with various means of rehabilitating multiple trails in Yosemite National Park.

The final problem, impromptu trail development, is a catchall category for recreational impacts outside campsites, designated trails, and grazing areas. The most frequent impacts are "fishermen's trails" around lakes and along streams and trampling damage at scenic attractions, such as waterfalls and other scenic viewpoints. This situation is the one most analogous to the random trampling generally studied by British recreational ecologists. Although seldom mentioned in more than casual observations, this type of impact is probably most similar to what happens on campsites. Vegetation is lost; what survives is floristically, morphologically, and physiologically distinctive; organic horizons are removed; and soils are physically, biologically, and probably chemically altered.

Managers' Perceptions of Problems

Two studies have attempted to assess the prevalence and significance of impact problems by querying wilderness managers about various problems that make it difficult for them to achieve management objectives. In a survey of managers of selected wildernesses, 80 percent of the managers that responded to an open-ended question about important problems mentioned trail and campsite deterioration. The only other frequently mentioned recreation-related problem was user conflict (Godin and Leonard 1979). The conclusion that trail and campsite deterioration is, in the opinion of managers, the most prevalent recreation-related problem in wilderness was corroborated in a more extensive survey of managers of all units in the National Wilderness Preservation System (Washburne and Cole 1983). Trail deterioration and campsite deterioration were considered to be a problem by 76 and 72 percent of the managers, respectively. This compared with perceived problem frequencies of 51 percent for crowding, 36 percent for impacts on wildlife, and 22 percent for water pollution.

This finding that campsite and trail deterioration is the most frequent recreation problem in wildernesses, at least in the opinion of managers, suggests that ecological problems occur at lower use levels than social problems. Reviewing recreation problems in England, Munton (1972) also concluded that "the thresholds of the semi-natural biological system are exceeded . . . before the psychological threshold resulting from overcrowding."

In addition to being a problem in more wildernesses, campsite and trail deterioration are also the most widespread problems within individual areas. When asked if problems occurred in "a few places" or in "many places," the number of wildernesses (out of 152) with problems in many places were 51 for campsite deterioration, 39 for trail deterioration, 19 for crowding, 9 for wildlife disturbance, and 3 for water pollution (Washburne and Cole 1983).

Beyond assessing the prevalence of problems, one would also like to assess the importance of problems. This, however, is where the insufficient research base becomes readily apparent. In contrast to considerable research on the extent to which crowding detracts from visitor satisfaction (an important management objective in wilderness), there has been little attempt to assess the importance of vegetation and soil deterioration in terms of not maintaining natural conditions (the primary management objective in many people's opinion). We desperately need a better understanding of the significance of these prevalent ecological impacts on trails and campsites.

Spatial Distribution of Impact

One component to be addressed when considering the significance of impacts is the areal extent of impact. On this basis, one might conclude that impacts are not highly significant. Recreational use is highly concentrated along a few major trails and at a few popular destinations. This leaves the vast majority of wilderness essentially unvisited and therefore undisturbed by recreational use. In the Adirondacks, Rechlin (1973) estimated that only 0.01 percent of the area had been disturbed by camping. In the Great Smoky Mountains, where camping is allowed only on designated sites, a conservative estimate of camping disturbance was 0.06 percent of the backcountry (Bratton and others 1978). In two relatively popular drainages in the Eagle Cap Wilderness, where camping is allowed almost anywhere, Cole (1981a) estimated 0.2 percent was disturbed by camping. Finally, 1.3 percent of a very popular lake basin in the Eagle Cap had been disturbed by camping (Cole 1982c). Although this percentage is still small, it is concentrated in the places where visitors spend most of their time—so evidence of human impact is omnipresent—and certain types of environments (flat, rock- and brush-free locations) may all be disturbed by camping.

Other areas have been disturbed by trails and grazing. Trail disturbance varies greatly between areas. Results of a survey of wilderness managers (Washburne and Cole 1983) indicate that the highest trail densities are in the Sawtooth and Joyce Kilmer-Slickrock Wildernesses. Assuming a 9-foot-wide swath of disturbance, about 0.7 percent of these wildernesses has been disturbed along designated trails. Over an entire wilderness, trails and campsites are unlikely to disturb more than 1 percent of the area. Locally, however, they could disturb a much higher percentage of popular lake basins and lakeshore areas.

More significant, in many places, is the area disturbed by grazing. In part of the Eagle Cap Wilderness, this amounted to about 1.3 percent of the area—almost three times the area of trails and campsites (Cole 1981a). However, more important than areal extent is the fact that grazing often occurs on relatively rare ecosystem types. In some places all representative examples of some meadow types may be disturbed by grazing. This, without question, represents a serious problem and a change that is essentially irreversible. The frequency of such situations has never been assessed, but it argues for the wisdom of a policy, such as that proposed for Sequoia/Kings Canyon National Parks, prohibiting grazing of representative examples of most meadow types. The near-complete lack of research on grazing impacts and their management in wilderness is a serious research gap.

Concentration of use on a small proportion of the wilderness can and has been considered both a bad and a good thing. Some have argued that most impact problems result from excessive concentration of use (Stanley and others 1979). In their survey of managers, Washburne and Cole (1983) reported that the most frequent response to an open-ended query about management's most significant problem was impact as a result of concentrated use. Others suggest that this tendency for use to be concentrated is what has kept wilderness resources as undisturbed as they currently are (Cole and Fichtler 1983). Clearly, managers should actively manage spatial patterns of use and impact. There may be situations where excessive impact at concentrated use sites should be reduced through use dispersal; there are also likely to be situations where undisturbed areas should be preserved through maintenance of existing patterns of use concentration.

The major threats to the concentration of impact are cross-country travel and the proliferation of campsites in destination areas. Neither have been examined in much detail. Cross-country travel, if use is frequent enough, can lead to the development of undesired impromptu trails. Where this occurs, the only management options are either to restrict use or to designate official trails and confine impact to those trails. The campsite proliferation problem was documented by Cole (1982c) in the Eagle Cap Wilderness, where 221 campsites were found around two subalpine lakes. Where use levels are high, campsite proliferation can only be avoided by confining use—either through education or regulation—to a small number of established sites. Where use levels are low, both highly impacted sites and site proliferation can be avoided through use dispersal and promotion of minimum impact camping techniques. Management of both the impromptu trail problem and the campsite proliferation problem would profit from more research on the relationship between use and impact discussed below. Such research could identify, for major ecosystem types, use thresholds beyond which trail and campsite problems are likely to develop.

On a smaller scale there are distinctive impact patterns on individual campsites. We have already described differences in amount of impact between the campsite core and fringes of the site. Often this concept of radial impact, with impact decreasing with distance from the campsite center, breaks down. Campsites may be linear or L-shaped, and they often include undisturbed "islands" and disturbed "satellite" sites. McEwen and Tocher (1976) proposed recognizing three zones for developed campsites: "(1) impact zone, the corridors of heavy use between and around site facilities; (2) intersite zone, the relatively undisturbed areas between the corridors of heavy use; and (3) buffer zone, the rarely disturbed areas at the border of the site." They prescribed different management strategies for each zone, emphasizing concentrated use on a small impact zone, creating intersite zones, and preserving the buffer zone.

In wilderness, these impact patterns are less pronounced because unstructured campsites have a more diffuse zonation (Hart 1982). In heavily used areas, however, facilities such as fire grates and toilets are not uncommon, and they tend to structure zonation patterns. In 1980, 19 percent of wildernesses had open-pit toilets, 15 percent had enclosed outhouses, 12 percent had shelters, 10 percent had constructed fireplaces, 8 percent had tables, and 7 percent provided a potable water supply (Washburne and Cole 1983). Clearly, impact could be reduced by channeling use between such facilities through careful design during construction and maintenance. Policies regarding fire rings—whether they are broken up or left—will also affect impact patterns; impacts are likely to be more extensive where fire rings are frequently broken up and rebuilt in different parts of the site (Cole and Dalle-Molle 1982). There is also a strong tendency for campsites to expand in area over time (Merriam and others 1973). Amount of expansion is likely to be greatest in open vegetation types and in places where party size limits are high and where party members tend to seek privacy from each other (for example, on outfitted trips made up of numerous unrelated individuals or groups). It should be possible to confine expansion, channel use to selected satellite sites where necessary, and protect most of the buffer zone from indiscriminate expansion. Despite increased expenditures by managers on site maintenance, no research evaluating existing efforts or suggesting improved techniques has been conducted. The benefit/cost ratio of such work would be high.

Considerable effort is also going into rehabilitating campsites, usually after permanently closing them. Research on this subject will be described more fully later. However, closures are sometimes temporary and in some cases (for example, the Boundary Waters Canoe Area and Eagle Cap Wilderness) some rehabilitation is attempted without curtailing use. A particularly important goal of such efforts is to get some tree reproduction on sites where it has been eliminated by trampling. Designing impact zones and protected intersite "islands" is critical to successfully rehabilitating any site that will be used again.

Trails have a sharp disturbance gradient perpendicular to the trail. The central trail tread is usually devoid of vegetation and organic matter and is highly compacted. Disturbed strips, on either side, are usually vegetated, but vegetation stature is short, cover is often low, and composition is different from adjacent undisturbed vegetation. If in a forested zone, trees are absent along the tread and disturbed zones. Lack of an overstory affects microclimate along the trail. The width of these zones is quite variable, but from the perspective of the entire wilderness, they are always narrow. The combined width of tread and disturbed zones is typically about 9 feet but can be much wider, particularly in meadows and where the trail is muddy.

The lateral expansion of trails can be controlled. Stock, in particular, tend to walk on the downslope side of trails. This breaks down the outer edge of the trail so that more soil must be brought in to rebuild the trail. The result is a wide trail, a much wider zone of disturbance, and an ongoing maintenance problem (Whitson 1974). Placing boulders on the outside of the trail can force stock and hikers to walk on the inside of the trail. Other techniques, such as avoiding excessive trail brushing, locating the trail in rough terrain (Bayfield 1973), and bridging wet areas can be used to limit lateral expansion.

Temporal Aspects of Impact

The few studies that have examined rate of deterioration on newly opened sites show that impacts occur very rapidly, even with moderate use, during a break-in period that seldom lasts more than several years (LaPage 1967; Merriam and others 1973; Legg and Schneider 1977). On new campsites in the Selway-Bitterroot Wilderness, vegetation loss approximated that on older campsites within 5 years. Loss of organic matter and resulting exposure of mineral soil occurred more slowly, but after 8 years was as pronounced as on older sites (Cole and Ranz 1983). On more heavily used sites, these changes can occur more rapidly. Merriam and others (1973) recorded near maximum levels of soil compaction after just 2 years' use on Boundary Waters Canoe Area sites. LaPage (1967), working on developed campsites, found that vegetation cover reached minimum levels after the first year of use. Where use levels are low, however, one study documented very little impact caused by camping (Leonard and others 1983).

After the break-in period comes a period of dynamic equilibrium (Hart 1982) in which seasonal and annual fluctuations predominate, in contrast to the unidirectional deterioration that occurs during the break-in period. On developed sites, Echelberger (1971) and Magill (1970) found little deterioration and some improvement over 5 years of use on long-established campsites. In the Boundary Waters Canoe Area (Merriam and Smith 1975; Merriam and Peterson 1983), the most pronounced change over time on sites at least 5 years old was an increase in campsite size. There also may be increases in tree damage, which is cumulative, in contrast to trampling damage, which after a few years should fluctuate around an equilibrium level (Hart 1982). Without management intervention, the dynamic equilibrium period will be followed, on forested sites, by a dying forest; sites must either become nonforested or be abandoned. The time it takes to reach this deteriorated state is determined by the longevity of tree species; it will usually be measured in hundreds of years, so we have few examples. However, the susceptibility of aspen to canker diseases following mechanical injury from recreationists makes the life span of developed campsites in aspen about 30 years (Hinds 1976). Maroon Lake Campground, an aspen campground in Colorado, is one of the first documented examples of a campground beyond the dynamic equilibrium phase (Johnson and Hinds 1977).

The first study to seriously question the dynamic equilibrium concept was Marion's (1984) recent examination of conditions on campsites in the Boundary Waters Canoe Area. He examined differences in amount of impact on campsites in three age classes: 5 to 10 years old, 11 to 13 years old, and more than 13 years old. There was little difference between the 5- to 10-year-old and 11- to 13-year-old sites, but the more-than-13-year-old sites had more root exposure and tree damage; they also were larger, and had experienced greater increases in bulk density and shifts in species composition. The larger area and greater root exposure and tree damage were as expected; however, the other changes challenge the notion of equilibrium. Differences in amount of impact are not pronounced; after statistically controlling differences in amount of use, an overall index of impact showed that 5- to 10-year-old sites had experienced 86 percent as much change as the over-13-year-old sites. However, this does suggest that trampling damage may increase slightly over time. Unfortunately, in addition to being older, these sites are also unique in their use history and location. They were developed by campers, prior to restrictions on party size and camping techniques, in prime locations. The younger sites were developed by the Forest Service, with concern for design and durable locations, and did not go through the "frontier lifestyle" phase the older sites did. It is impossible to separate these factors from campsite age and conclude that today's young sites will, over time, become like today's old sites. This is a good illustration of how lack of longitudinal studies forces reliance on cross-sectional studies that cannot, by themselves, provide definitive answers to questions such as how impacts change over time. For more detail on campsite changes over time, refer to the paper by Cole and Marion presented elsewhere at this conference.

Two factors contribute to the tendency for trampling damage to equilibrate. The first is that many types of impact reach a maximum limit. For example, bulk density will eventually reach a limit above which much heavier loads would have to be applied to cause an increase. The second factor is the existence of homeostatic controls or negative feedback loops. A pattern of impact and recovery, such as erosion of leaf litter every summer and accumulation of leaf litter every fall, tends to keep litter cover fairly constant. In a few cases, the impacts of recreation use actually decrease the likelihood of further deterioration. On trails, and to a lesser extent on campsites, soil compaction following trampling can stabilize the soil surface, making it less prone to further erosion (Malin and Parker 1976). It is still a highly altered environment, inhospitable for vegetation, but less likely to erode than it was in the phase between initiation of development and the formation of a compacted surface.

In a similar manner, trampling disturbance may promote the invasion of trampling-tolerant species. On newly opened developed campsites, LaPage (1967) documented an initial rapid loss of vegetation cover. After this initial drastic loss, however, vegetation cover during the second, third, and fourth years of use actually increased as trampling-resistant, often exotic species, invaded the site. The resultant ground cover, being relatively tolerant of recreation use, resists further cover loss. These homeostatic controls are much less effective in environments where recovery processes are extremely slow or where there are few "weedy" invader species. Alpine ecosystems are deficient on both of these counts and, therefore, deterioration can be unusually severe once use exceeds tolerance thresholds.

Studies of recovery rates on recreation sites are almost as rare as studies of deterioration over time. Longitudinal studies of 3 years' recovery on campsites were done in Sequoia National Park (Stohlgren 1982) and the Selway-Bitterroot Wilderness (Cole and Ranz 1983). Cross-sectional studies in the same areas estimated recovery over 15 years (Parsons and DeBenedetti 1979) and 5 years (Ranz 1979). Willard and Marr (1971) investigated recovery of tundra over a 2-year period near parking areas in Rocky Mountain National Park. Others have investigated the effectiveness of cultural means of increasing recovery rates (a topic discussed below) and have followed recovery after artificial trampling experiments for periods up to 8 years.

Recovery periods are universally long, but they have only been examined in harsh environments where low resilience would be expected. Assuming a linear recovery rate in the future, a cross-sectional study of 5 years' recovery allowed Ranz (1979) to predict recovery of predisturbance vegetation cover in 16 years. However, a followup study indicated recovery rates were not constant or linear functions (Cole and Ranz 1983). Moreover, core areas of campsites require much longer recovery periods than fringe areas of campsites. Stohlgren (1982) estimated recovery periods for vegetation cover—again assuming linear rates—of 56 years in the core and only 5 years in the periphery. Recovery periods for bulk density were 36 years in the core and 11 years in fringe areas. In a cross-sectional study in the Boundary Waters Canoe Area, estimated recovery periods were 20 years for vegetation cover, 50 to 60 years for a return to normal species composition, and 30 to 40 years for bulk density (Marion 1984). After 15 years without use, litter accumulation and soil penetration resistance on campsites in Kings Canyon National Park had reached inferred predisturbance levels, but fuel accumulation was still low and tree mutilations, social trails, and vegetation deterioration were still evident (Parsons and DeBenedetti 1979).

Two major implications of rapid deterioration and slow recovery are that impacts are inevitable with use and that they are unlikely to be managed efficiently through adoption of a rest-rotation system. Rest-rotation, an often-suggested management practice in which sites are periodically closed and then reopened after recovery, would lead to many closed sites for each open site, as long as recovery periods are longer than deterioration periods. Since all research shows recovery periods to be many times greater, rotation appears to be generally impractical.

There is some indication that recovery can be relatively rapid if use only occurs for 1 year (Willard and Marr 1971 and several experimental trampling studies). Some wildernesses, such as Shenandoah National Park, where resilience appears to be high, have been trying variations of rest-rotation systems. Research evaluating the relationship between duration of impact period and recovery rates in more resilient ecosystems and the success of management systems such as the one at Shenandoah would expand our understanding of how recreation sites change over time.

On trails, some segments are relatively stable while others deteriorate rapidly. Generally, most change occurs during initial construction of the trail. Subsequent "problems," such as erosion, probably also occur rapidly. Old, traditional trails in Great Britain, for example, do not seem to be getting wider with age (Bayfield 1985). Recovery rates, unless assisted, are likely to be even more lengthy than those on campsites. In many cases, trail erosion is likely to continue even after all use has been curtailed. All one has to do is look at the slow recovery of trails abandoned after rerouting to see this.

Recovery rates on trails are highly variable, however. Experimentally trampled trails in the southern Appalachians were almost completely revegetated after just 1 year (Studlar 1983), while vegetation cover was only 24 percent of that on controls after 6 years of recovery in dry alpine meadows in Glacier National Park (Hartley 1976). Rates are highly variable even within the same general area (Leonard and others 1985). For example, 5 years after being experimentally trampled by horses, vegetation cover of a grassland (*Festuca-Poa*) was 100 percent of normal; cover in a forest (*Pinus-Vaccinium*) was only 26 percent of normal (Weaver and others 1979). In addition to faster recovery in nonforested areas, observations suggest that wet places revegetate more rapidly than dry places. Natural infilling of severely eroded trails may never occur, except in depositional locations. Extensive rehabilitation work is often the only feasible means of bringing about recovery.

Factors that Influence Amount of Impact

Perhaps the greatest increase in understanding over the past 10 to 15 years has come from investigations of factors that influence amount of impact. This probably reflects the fact that such studies, while requiring more sophisticated research designs and analyses than descriptive surveys, can still be completed over a short period of time using cross-sectional techniques. Understanding the factors that influence impact is of paramount importance because managers can manipulate these factors to control amount and type of impact. This subject is the ecological analog to the so-called carrying capacity research by social scientists in which factors affecting crowding and visitor satisfaction have been studied.

The principal factors that have been identified are (1) amount and frequency of use, (2) type and behavior of users, (3) season and time of use, and (4) environmental conditions where recreation use occurs. While these are the factors that determine **intensity** of impact at any point of use, the **areal extent** of impacts is also affected by the spatial distribution of use, particularly its level of channelization. Although seldom the direct subject of research, it is clear that, everything else being equal, greater concentration of use leads to disturbance of less of the wilderness. When developing management strategies, both the factors that influence intensity of impact and those that influence level of use concentration need to be considered.

Amount and Frequency of Use.—Amount of use, strictly defined, should refer to the total number of people that have ever used a site or trail. However, the effect of a given number of users is likely to be modified by the number of years over which that use is spread. One would intuitively expect that, for a given number of users, spreading use over more years would cause less impact because this offers more opportunity for recovery. This hypothesis has never been adequately tested, however. If true, it would justify the tendency to use amount of use per year—a frequency measure—instead of total use as an independent variable.

Even when using measures of amount of use per year, there is some question about the importance of how that use is distributed over the year. Here some very limited data from trampling experiments suggest that, for a given amount of use, the distribution of that use over the year is a relatively unimportant factor (Cole 1985c). For example, the effect of 50 parties of two (100 total visitors) should be about the same as two parties of 50. While this seems reasonable on trails, it is not a reasonable assumption on campsites, where party size makes a difference, particularly to campsite size. Generally, recognizing considerable ignorance of the importance of frequency, studies of trail impact should use measures of total visitors per year (hopefully comparing trails of about the same age and that have not experienced major recent increases or decreases in use). In campsite studies, party-nights per year is probably as valid a measure as visitor-nights per year; both are probably important. In reality most studies have had to rely on ordinal use estimates of occupancy rates because these are all that are available. However, each of these measures has different implications that should be kept in mind.

Conventional wisdom has often held that amount of use is the most important factor influencing amount of impact. Such thinking has been supported by calling deteriorated sites "overused" and by proposing that solutions can be found by prescribing a "carrying capacity." Research shows that such thinking is oversimplified at best, and erroneous at worst. The importance of amount of use varies between environments, between activities, with impact parameter, and with the range of use levels being examined. In addition, effects differ depending on whether concern is with rate, intensity, or areal extent of change.

Research on the relationship between use and impact began in the early 1960's, with Frissell and Duncan's (1965) cross-sectional analysis of Boundary Waters Canoe Area campsites and Wagar's (1964) experimental trampling study in a recreation area in Michigan. Both studies examined the effect of different use levels on loss of vegetation cover. Frissell and Duncan (1965) found that the most lightly used campsites (0 to 30 nights per year) had lost 80 percent of their inferred original cover, while heavy use sites (60 to 90 nights per year) had lost only 7 percent more—87 percent. Wagar (1964) also found that although impact does increase as use increases, small amounts of use cause substantial amounts of impact. This relationship between amount of use and loss of vegetation is shown in figure 4. The curves are asymptotic, rather than linear. They have a single inflection point that separates the rapidly rising segment of each curve from the segment where increase in amount of impact is small.

The shape of this curve and the location of the inflection point have important implications for management. Attempts to limit vegetation damage by keeping use levels low will only be effective where use levels can be kept substantially below the use thresholds that correspond to the inflection points—those use thresholds are points X(a) and X(b) on the X axis. This may be impossible to do in portions of wildernesses that receive even moderate levels of use. Several studies in subalpine forests suggest that use levels of only five nights per year exceed these threshold levels (Cole and Fichtler 1983). In such places, concentration of use on a small number of sites appears to be the most appropriate strategy for minimizing vegetation loss.

Most studies have examined only sites with use levels beyond those that correspond to the inflection points on the curve. Consequently cover differences are not substantial and, generally, not statistically significant. One exception is Coombs (1976), who found that very lightly

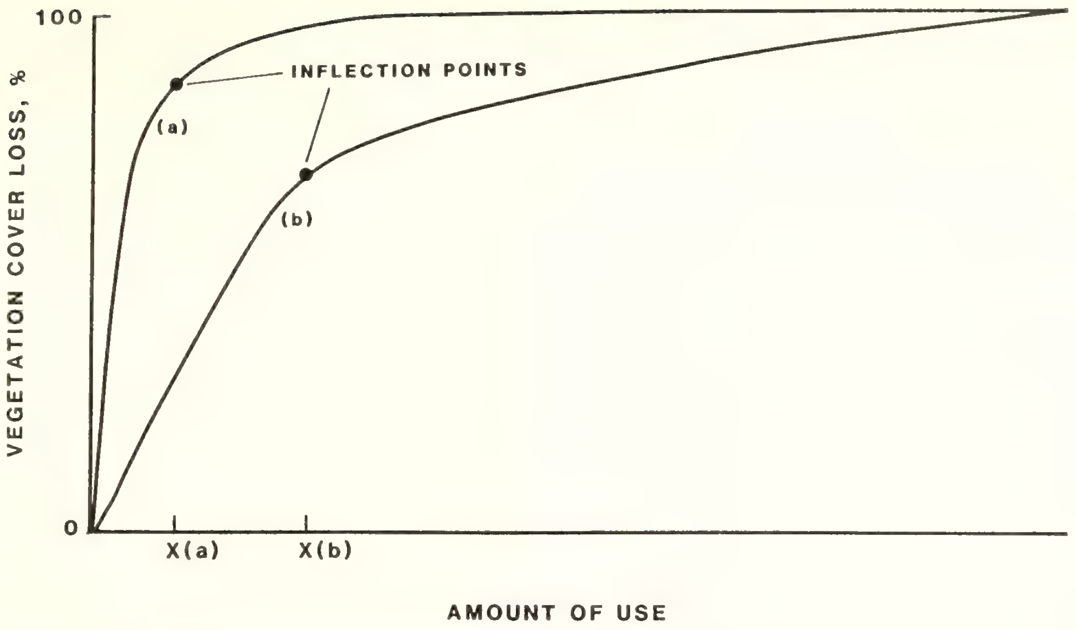


Figure 4.—The general relationship between amount of use and loss of vegetation cover for (a) a fragile vegetation type and (b) a more resistant type.

used sites, in what is now the Frank Church-River of No Return Wilderness in Idaho, had experienced less than 40 percent as much vegetation loss as heavily used sites.

Below use thresholds, even slight reductions in use can reduce vegetation loss substantially. This suggests a real opportunity to minimize impact in remote, lightly used places. In portions of wilderness where use levels can be kept well below these thresholds, it appears most appropriate to spread people out over a very large number of sites so that use levels are as low as possible. For this to work, visitors must be taught to use unused rather than lightly used sites, to practice low-impact camping, and to try to eliminate all traces of their stay when they move on.

Identification of inflection points and use thresholds offers tremendous potential for management because they can be used to choose between the opposing strategies of concentration and dispersal. Virtually every wilderness in the country could profit from employing both of these strategies in some part of their area.

Curvilinearity and the location of inflection points vary with differences in type of use and differences in environmental durability, however. In figure 4, curve (a) depicts the use/impact relationship for a quite fragile vegetation type, while curve (b) depicts the same relationship for a more durable type. Curve (b) is not as strongly curvilinear, and the use threshold associated with the inflection point—X(b)—comes at a higher level of use. If managers can get people to camp in type (b) rather than type (a), about twice as much use can be absorbed before the need to adopt a concentration strategy arises.

In one of the few studies undertaken on resistant vegetation types, Dunn and others (1980) examined developed campgrounds in the Atlantic Coastal Flatwoods region of South Carolina. They found no significant loss of vegetation cover except on heavy use sites. As in most other studies, inadequate measures of use make it impossible to establish use thresholds for these South Carolina campsites. More research, employing better use estimates and controlled experiments, could enable us to establish use thresholds for important environments across the country.

Hylgaard and Liddle (1981) hypothesized a rather different shape to the use/impact curve. They fitted cover loss, following experimental trampling, to a logistic equation. Logistic curves have three segments separated by two inflection points. At the very lowest use levels differences in amount of use have little effect on cover loss; vegetation can tolerate a certain amount of use before plants are killed. Above the first inflection point, cover loss increases rapidly with increasing use until the second inflection point is reached; beyond this point increases in use have less and less effect on vegetation cover. While such a model is intuitively appealing, there are few data to evaluate it.

Data from an experimental trampling study being conducted in Montana are presented in figure 5. Data are for two vegetation types that had been trampled for 2 successive years. A pass is a one-way walk down a trampling lane. The use/impact relationship for the spruce forest exhibits the highly curvilinear form of a fragile vegetation type—with an inflection point at around 200 passes per year. That corresponds to about 2 nights of camping use per year by an average party (Cole 1985c). In this forest, once use levels reach 2 nights per year, further increases in use cause little additional vegetation loss. Unless use levels can be kept at or below 1 night per year, it seems most appropriate to concentrate use on a few of these forested sites.

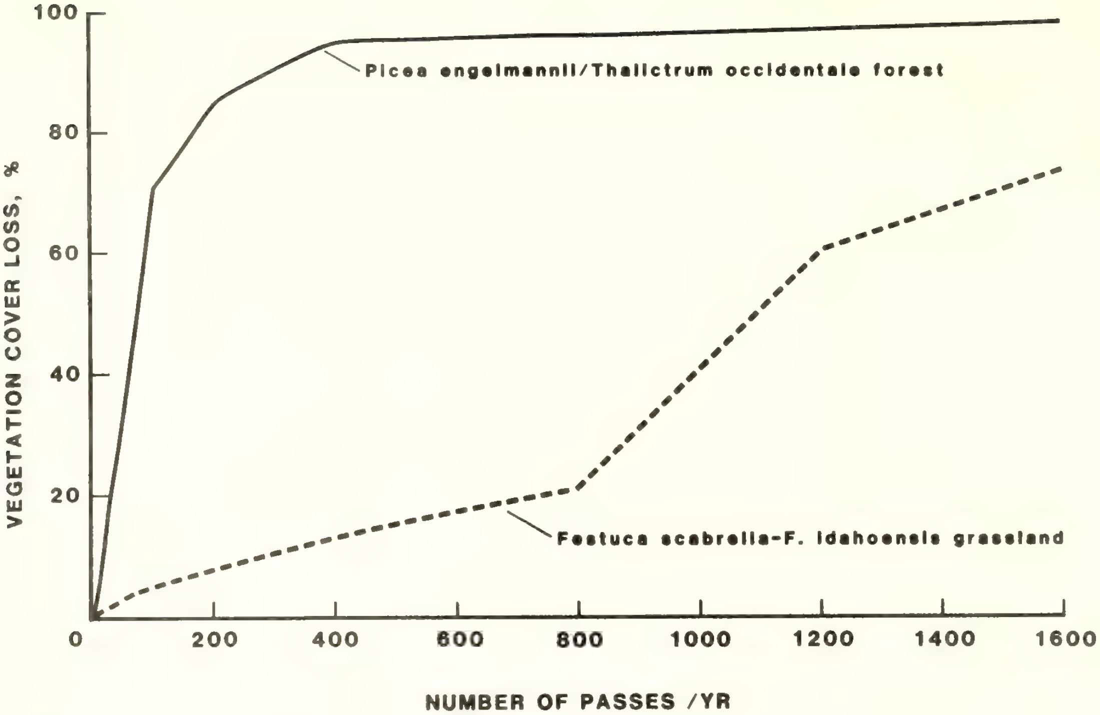


Figure 5.—The relationship between number of passes per year and vegetation loss (as a percent of original vegetation cover, adjusted for changes on controls) for two vegetation types in western Montana. Trampling was applied for two seasons.

The grassland, however, exhibits the form of a logistic curve with two inflection points. Below 800 passes per year, further reductions in use have little effect. In other words, there is some initial resistance to vegetation loss before further increases in use cause a substantial loss of vegetation. Apparently, only the most resistant vegetation types have this form.

Another complication to our original simple model comes from the fact that the shape of the curve varies with the type of impact being studied. Figure 6 shows some data from a recent study of campsites in the Boundary Waters Canoe Area (Marion 1984). For each parameter, amount of change on low-, moderate-, and high-use sites has been expressed as a percentage of change on the high-use site. Degree of curvilinearity and use thresholds differ between parameters. Just as vegetation types vary in their susceptibility to any type of impact, the susceptibility of a site to different types of impact is also variable. Those parameters, like vegetation cover, for which a highly curvilinear relationship exists, include bulk density, penetration resistance, macropore space, infiltration rate, changes in soil chemistry, loss of tree seedlings, and tree damage (Young and Gilmore 1976; Legg and Schneider 1977; Dunn and others 1980; Cole and Fichtler 1983; Marion 1984). Loss of organic horizons, exposure of mineral soil, severe root exposure, and site enlargement are all changes related to use in a less curvilinear manner (Coombs 1976; Young 1978; Cole and Fichtler 1983; Marion 1984). There is more inherent resistance to these types of change; inflection points and use thresholds are usually higher. Changes in these parameters are easier to limit through manipulation of use intensities on campsites.

The final complication is that even the susceptibility rankings for these parameters do not apply universally. For example, in Grand Canyon National Park, exposure of rock and mineral soil increased as rapidly with increasing use as vegetation loss and more rapidly than increase in penetration resistance (Cole 1985b)—a reversal of the order in the Boundary Waters Canoe Area.

Research does suggest a strong relationship between amount of use and rate of vegetation loss. For example, in an experimental trampling study on alpine meadows in Mount Rainier National Park, vegetation cover was reduced to 50 percent of control values in 3 weeks when trampled at 75 passes per week. At 18 passes per week, it took 8 weeks of trampling for cover to be reduced to 50 percent of controls (Singer 1971). The areal extent of vegetation loss is also strongly related to amount of use (Bratton and others 1978; Cole 1982b). The finding that, at all but very low use levels, increased use has little effect on intensity of vegetation loss and a pronounced effect on area of loss, suggests the value of concentrating and channeling use on a small proportion of any area (Cole 1981b).

On trails, vegetation cover, bulk density, penetration resistance, and trail width relationships are highly curvilinear, as they are on campsites (Dale and Weaver

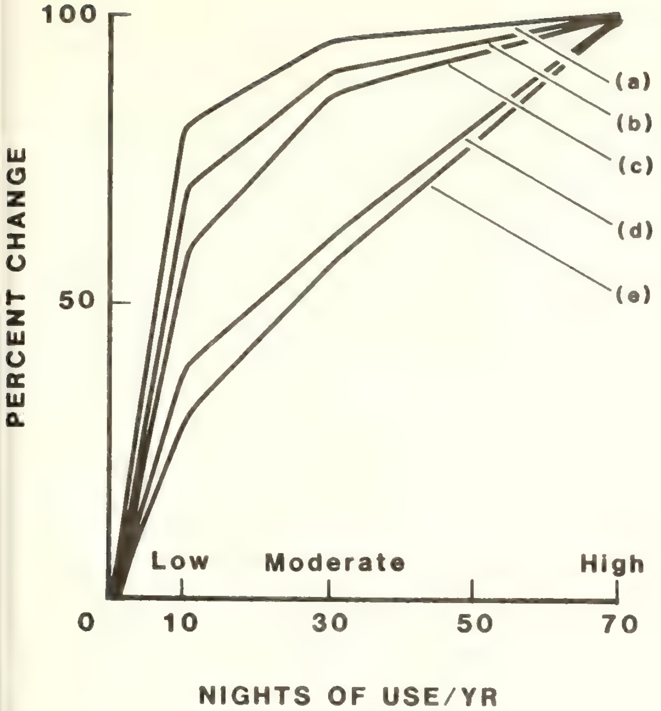


Figure 6.—Relationship between amount of use and (a) tree damage; (b) loss of vegetation cover; (c) increase in penetration resistance; (d) increase in exposed roots, mineral soil, and rock; and (e) campsite area on campsites in the Boundary Waters Canoe Area (Marion 1984). Change is expressed as a percentage of change on high use sites. Numeric use levels are estimated from ordinal classes of low (0 to 12 nights per year), moderate (20 to 40 nights per year), and high use (>60 nights per year).

1974; Crawford and Liddle 1977). Trail depth and the frequency of problems, such as muddiness, are generally not related to amount of use (Dale and Weaver 1974; Helgath 1975; Cole 1983b). Such situations relate more to location and design features, although they obviously must be triggered by some use or construction.

In sum, these results suggest that there is little value, in terms of reduced impact, in limiting use of constructed trails. On campsites, limiting use is only likely to be effective if use levels can be kept very low. This is possible in the majority of most wildernesses, but not in popular destination areas. In popular areas, counteracting the tendency for increased use to increase the areal extent of impact—through channeling and concentrating use—is one of the most effective means of minimizing impact. Because the tipping point for each of these opposing strategies—dispersing use to keep levels low or concentrating use to minimize areal extent—varies greatly between environments, use thresholds need to be identified for major ecosystem types.

Type of Use and Behavior.—The current vogue is to look to visitor education for solutions to wilderness management problems. This reflects a feeling, certainly true but never tested, that parties of the same size vary greatly in the damage they inflict. If all parties can be taught to minimize their impact, then impact problems will be reduced. There are certain problems (such as tree mutilation) that could be entirely eliminated through education. Much trampling damage would still occur, however, although at reduced levels.

Currently, over one-half of all wildernesses have educational programs (Washburne and Cole 1983); a number of studies of how to effectively communicate information to users have also been conducted (for example, Fazio 1979; Roggenbuck and Berrier 1981). In contrast, there has been very little research into what users should be taught. All published papers suggesting educational messages have been personal opinions not based on research. Although many ideas have merit and are not controversial, others are contradictory and oversimplified. Few take into account the need for varying behavior in different environmental and use situations. One exception is an article by Cole and Benedict (1983) that, following a review of literature, suggests different user responses to campsites in various stages of deterioration. It is wasteful to initiate major educational programs without investing some research in what the educational message should be.

One seemingly obvious statement that has frequently been made is that lug-soled boots are much more destructive than tennis shoes or shoes with flat soles. In this case, some research on the subject has been done. Three studies—all done on trails in the East—concluded that, at least under the conditions studied, lug soles are not substantially more destructive than other types of footwear (Whittaker 1978; Saunders and others 1980; Kuss 1983). Kuss, for example, found no significant difference in the volume of soil eroded from stretches of trail trampled by lug-soled and corrugated rubber-soled boots. This lack of difference was found despite increases in soil yield, after 600 and 2,400 trampling passes, that amounted to 1.4 and 1.7 times, respectively, the yield from undisturbed trail. Kuss suggests, however, that differences might be significant if soils were wet. Similarly, perhaps lug soles are more destructive of vegetation on campsites. We will not know unless more conclusive research is undertaken.

Research on the effects of various types of use has also been limited. In wilderness, differences related to party size and mode of travel (hikers vs. stock) are particularly important and amenable to control. The effects of party size have never been formally studied. There is little reason to suspect that large parties will have a more serious impact on trails than a number of small parties. On campsites, however, party size differences could be important.

In response to the need of large parties for more space, campsite area and the size of devegetated areas are likely to increase where sites are used by large parties. However, the severity of impacts in the central part of the campsite is unlikely to increase substantially. Per capita consumption of firewood is less with large parties (Davilla 1979), and reducing party size limits could have the undesirable effect of increasing the number of campsites. Most of these likely outcomes are speculative; they have not been researched. It is fairly safe to conclude that the current common party size limits of 15 or 25 have had little effect, one way or the other, on recreational impacts.

Differences between impacts caused by hiking parties and parties with stock have received a little more attention, but research has been surprisingly limited. Three studies have compared impacts using experimental trampling (Nagy and Scotter 1974; Douglas and others 1975; Whittaker 1978; Weaver and Dale 1978), two have compared impact on campsites (Frissell 1973; Cole 1983a), and one has compared impact on trails (Dale and Weaver 1974). In addition there are papers by McQuaid-Cook (1978) and Summer (1980) on horse trails and by Strand (1979) on horse effects on experimental trails, as well as the limited research, discussed earlier, on the effects of stock on grazing areas.

Many of the impacts caused by stock are similar to those caused by hikers except that they are more pronounced. Experimental trails produced by 1,000 horse passes were 2 to 3 times as wide and 1.5 to 7 times as deep as trails produced by 1,000 hiker passes. Bulk density increased 1.5 to 2 times as rapidly on horse trails. One-half of the vegetation was lost after 1,000 hiker passes and 600 horse passes in a grassland and after 300 hiker passes and only 50 horse passes in a forest (Weaver and Dale 1978). In a grassland in Waterton Lakes National Park, experimental trampling by horses destroyed vegetation cover four to eight times as rapidly as trampling by humans (Nagy and Scotter 1974). This suggests that multiple trailing and the development of impromptu trails will occur much more rapidly with stock use than with hiker use. Moreover, the trails created will be wider, deeper, more compacted, and less vegetated.

On existing trails, horse use caused more pronounced increases in trail width, trail depth, and litter loss than hiker use. While hiker use tended to stabilize the trail surface, horse use loosened the soil, making it more prone to erosion (Whittaker 1978). McQuaid-Cook (1978) suggested that it is this tendency for shod hooves to loosen soil that leads to the more pronounced incision of equestrian trails documented by Dale and Weaver (1974). The tendency for stock to walk on the downslope side of the trail probably explains the greater width of equestrian trails. Although never studied, equestrian trails are "brushed out" to a greater height and width, resulting in a wider swath of vegetation alteration, and they frequently require more elaborate engineering and more frequent maintenance.

On campsites, quantitative differences between hiker and stock impacts are even more pronounced. More significantly, there are more qualitative differences in type of impact. Although such differences are readily obvious, they have seldom been documented. Frissell (1973) found a sample of sites used by stock parties in what is now the Lee Metcalf Wilderness, MT, to be 10 times as large and have seven times as much exposed mineral soil as backpacker-only sites.

In a more detailed study by Cole (1983a) in the Bob Marshall Wilderness, stock sites were six times as large as backpacker sites. They had over four times as large a devegetated area; they had 11 times as many damaged trees and 25 times as many trees with exposed roots. Stock sites had been more extensively invaded by exotic plants, had lost more of their organic horizons, were more compacted, and had slower infiltration rates. These differences result primarily from the much greater trampling force of horses' hooves and the need to keep horses confined, usually by tying them to trees. Additional impacts result from grazing.

Season of Use.—Theoretically, there are many reasons to expect impact to vary with the time of year use occurs. In particular, soil moisture levels and the phenology of plants when trampling occurs should influence amount of impact. The effect of soil moisture level on the magnitude of trampling impacts on soils was investigated experimentally by Jones (1978). Impacts, particularly loss of macropores, were generally greater at high soil moisture levels. Vegetation damage inflicted by horse trampling was also greater and lasted longer in a wet meadow than in a dry meadow (Strand 1979).

The effect of season of trampling on vegetation loss has been examined experimentally in several studies. Singer (1971), working in an alpine meadow at Mount Rainier, found that vegetation cover was not significantly affected by the time of summer (July 3-August 13) at which trampling occurred. In 10 vegetation types in Waterton Lakes National Park, Canada, Nagy and Scotter (1974) found no consistent difference between trampling in early season (early June-early July) and midseason (late July-early August). In both of these studies, however, no pretreatment measurements were taken, and recovery periods between treatment and measurement were longer for the early season treatment. In a subalpine meadow in Yosemite National Park, Holmes and Dobson (1976) studied differences in the effect of midseason (early August) and late season (early September) trampling on the cover of 14 species. Late season trampling was substantially more damaging to nine species and slightly less damaging to one species; no seasonal difference could be detected for the other four. They attribute this higher vulnerability in late season to reduced plant vigor and drier, more brittle plant parts. There may, however, be little relationship between cover loss immediately after trampling and cover at some time in the future. Early season defoliation of forbs and grasses, for example, has a particularly severe effect on carbohydrate reserves (Donard and Cook 1970). This will affect vigor, reproductive success, and, therefore, long-term vegetation conditions.

Our understanding of the importance of seasonality, then, is extremely limited. Effects appear to be most important on trails and in grazing areas. Most trail management problems can probably be dealt with—without significant research input—through maximizing the advantages of good location and incorporation of design features. Grazing management plans, however, would profit from area-specific research programs, similar to that of Sequoia/Kings Canyon National Parks, that evaluate seasonal differences in vulnerability (DeBenedetti and Parsons 1983).

Environmental Conditions.—Environments vary greatly in their ability to tolerate recreational use. Understanding this variability is difficult, however, because any one place may be resistant to one type of impact and susceptible to another. Moreover, one characteristic of a site, such as good drainage, may raise a site's tolerance level while another, such as a closed canopy, decreases it. Finally, there may be little congruence between resistance—the ability to tolerate use without changing—and resilience—the ability to recover from changes that do occur. More research done outside the field of recreational ecology can usefully add to our knowledge about this topic than any other, with the possible exception of site rehabilitation. Therefore, the following discussion will, of necessity, be more selective than others.

Environmental parameters that affect tolerance can conveniently be divided into vegetation characteristics, soil characteristics, and topographic characteristics. At a higher level of generalization one can also assess the influence of broad ecosystem-level characteristics. Macroclimate also affects tolerance but cannot be influenced by management and, therefore, is not discussed here.

Vegetational characteristics of import are the resistance of individual species, the floristic composition of the vegetation, vegetation cover, and vegetation structure or physiognomy. Of these, most work—starting with Bates (1935)—has been on the resistance of individual species to trampling (Speight 1973; Holmes and Dobson 1976). Morphological characteristics that generally make a plant more tolerant include:

1. A procumbent or trailing, rather than erect, growth form.
2. A tufted growth form.
3. Arming with thorns or prickles.
4. Stems that are flexible rather than brittle or rigid, particularly if they are woody.
5. Leaves in a basal rosette.
6. Small, thick leaves.
7. Flexible leaves that can fold under pressure.
8. Either very large or very small structure.

Physiological characteristics that increase tolerance include:

1. Ability to initiate growth from intercalary as well as apical meristems.
2. Ability to initiate seasonal regrowth from buds below the surface.
3. Ability to reproduce vegetatively and sexually.
4. A rapid growth rate.

Native species that have been identified as particularly resistant to trampling damage in United States wildernesses are listed in table 1. Species have been omitted when evidence is contradictory. For example, *Hieracium gracile* was considered resistant by Coombs (1976) and sensitive by Schreiner (1974), Hartley (1976), and Cole (1982b). Nonnative species are also common on recreation sites in U.S. wildernesses. A list of these species can be found in the paper by Marion, Cole, and Bratton presented at this conference. Some species, such as *Poa pratensis* and *Trifolium repens*, are remarkably widespread and prominent on disturbed sites. In their native habitat in England, they were originally identified as trampling-resistant species by Bates (1935).

Attempts to generalize about the relative tolerance of classes of plants can be useful, although the inevitable exceptions provide considerable ammunition for those who prefer to emphasize the site-specific nature of plant response. Even the response of different individuals within a species varies in response to phenotypic and ecotypic differences (Leney 1974). Survival varies with seasonal cycles, with changes in conditions such as cell turgor, and with differences in associated species. For example, in subalpine meadows in Yosemite, survival rates of a given species were generally about three times greater in mixed communities than in pure stands (Holmes and Dobson 1976).

As mentioned earlier, mature trees and graminoids are generally resistant, mosses are neither highly resistant nor highly sensitive, and lichens and tree seedlings are highly sensitive. Shrubs vary from quite resistant to moderately sensitive; heaths can be particularly susceptible (Emanuelsson 1985). Forbs vary from moderately resistant to highly sensitive. These guidelines, along with consideration of the morphological and physiological characteristics influencing tolerance, can be used to assess the relative durability of different vegetation types. Those types with more abundant resistant plants will generally be more resistant.

Quite a few analyses of the relative resistance of entire species assemblages have been made. The ones that can be most readily compared are the experimental trampling studies. Table 2 ranks 38 plant communities on the basis of their resistance to trampling. Unfortunately, these studies only apply to the initial resistance of plant communities because only damage following one season of trampling was evaluated. Resistance to sustained trampling and resilience are not assessed. Vegetation types for which resistance is relatively high but resilience is low, such as many alpine vegetation types, are rated as resistant even though they may be poor sites for particular types of recreation use and facilities. Also, some very fragile types, such as lush forest/forb types, recover very rapidly after disturbance, if use is not continuous. For example, the "fragile" *Pinus contorta/ Thalictrum occidentale* type (table 2) had much more vegetation cover 1 year after trampling than the much more "resistant" *Dryas octopetala* type (Douglas and others 1975). Generally, those vegetation types with ground cover dominated by graminoids and matted forbs are more resistant than those dominated by shrubs and tall forbs. Studies of change on campsites and along trails in different vegetation types confirm this (del Moral 1979; Cole 1981a).

The effect of amount of vegetation cover on durability is complex. Some communities with a dense ground cover are highly resistant (for example, *Carex nigricans* meadow, Cole 1982b), but some sparsely vegetated types are also resistant (for example, *Pinus albicaulis/Juniperus communis*, del Moral 1979). Perhaps the most important characteristic is the amount of vegetation cover that can survive trampling, because dense vegetation reduces erosion potential.

Table 1.—Resistant native plant species in U.S. wildernesses

Species	Citation(s)
Agave utahensis	Cole (1985b)
Agoseris glauca	Cole (1983a)
Agrostis idahoensis	Thornburgh (1962)
Agrostis lepida	Stohlgren (1982)
Agrostis scabra	Cole (1983a)
Antennaria alpina	Holmes and Dobson (1976)
Antennaria dimorpha	del Moral (1979)
Antennaria lanata	Thornburgh (1962), Cole (1977, 1982b)
Arabis lyallii	del Moral (1979)
Arenaria capillaris	Singer (1971), Schreiner (1974), Hartley (1976), del Moral (1979)
Arenaria congesta	Cole (1985a)
Arenaria obtusiloba	Singer (1971), del Moral (1979)
Aster alpigenus	Singer (1971), Holmes and Dobson (1976), Cole (1977, 1982b)
Aster ciliolatus	Marion (1984)
Bernardia incana	Cole (1985b)
Bouteloua gracilis	Cole (1985b)
Carex aestivalis	Saunders (1979)
Carex bigelowii	Stelmock and Dean (1979)
Carex exserta	Lemons (1979)
Carex microptera	Cole (1982b)
Carex nigricans	Hartley (1976)
Carex phaeocephala	Schreiner (1974)
Carex podocarpa	Stelmock and Dean (1979)
Carex proposita	del Moral (1979)
Carex rossii	Coombs (1976), Cole (1977, 1982b, 1983a)
Carex scopulorum	Holmes and Dobson (1976), Cole (1982b)
Carex spectabilis	del Moral (1979), Cole (1982b)
Chrysothamnus nauseosus	Cole (1985b)
Coleogyne ramosissima	Cole (1985b)
Cowania mexicana	Cole (1985b)
Deschampsia atropurpurea	Thornburgh (1962), Schreiner (1974)
Deschampsia caespitosa	Marion (1984)
Ephedra spp.	Cole (1985b)
Eriogonum pyrolifolium	del Moral (1979)
Fallugia paradoxa	Cole (1985b)
Festuca idahoensis	Schreiner (1974)
Festuca scabrella	Cole (1985a)
Fragaria vesca	Marion (1984)
Geum rossii	del Moral (1979)
Haplopappus acradenius	Cole (1985b)
Juncus castaneus	Hartley (1976)
Juncus drummondii	Cole (1977)
Juncus parryi	Coombs (1976), Holmes and Dobson (1976), Cole (1977, 1982b), Stohlgren (1982)
Juncus tenuis	Sutton (1976), Marion (1984)
Lepidium lasiocarpum	Cole (1985b)
Lewisia columbiana	del Moral (1979)
Luetkea pectinata	Thornburgh (1962)
Luzula hitchcockii	del Moral (1979), Cole (1982b)
Muhlenbergia filiformis	Lemons (1979), Holmes and Dobson (1976), Cole (1982b)
Opuntia erinacea	Cole (1985b)
Oryzopsis kingii	Holmes and Dobson (1976)
Penstemon confertus	Cole (1983a, 1985a)
Penstemon davidsonii	del Moral (1979)
Penstemon procerus	del Moral (1979), Cole (1983a, 1985a)
Phleum alpinum	Hartley (1976)
Phlox diffusa	Singer (1971)
Plantago purshii	Cole (1985b)
Poa alpigena	Stelmock and Dean (1979)
Poa cusickii	del Moral (1979)
Poa epilis	Holmes and Dobson (1976)
Polygonum cilinode	Saunders (1979)
Rhus trilobata	Cole (1985b)
Rosa acicularis	Marion (1984)
Rubus strigosus	Marion (1984)
Schizachne purpurascens	Marion (1984)
Senecio pauperculus	del Moral (1979)
Senecio resedifolius	Hartley (1976)
Sibbaldia procumbens	Dale and Weaver (1974), Cole (1977, 1982b)
Smilax herbacea	Saunders (1979)
Solidago missouriensis	Cole (1983a, 1985a)
Solidago multiradiata	Cole (1977)
Stipa occidentalis	Cole (1983a)
Tauschia (Hesperogenia) stricklandii	Thornburgh (1962)
Trisetum spicatum	del Moral (1979), Stelmock and Dean (1979)
Xerophyllum tenax	Cole (1983a, 1985a)
Yucca baccata	Cole (1985b)

Table 2.—Relative resistance of plant community types to trampling damage

Plant community types[1]	Resistance to: Light[2] trampling	Heavy[3] trampling	Both[4]
1. *Pinus contorta/Thalictrum venulosum* (lodgepole pine forest)	VS	VS	VS
2. *Populus tremuloides/Heracleum lanatum* (aspen forest)	VS	SS	VS
3. *Populus tremuloides/Symphoricarpos albus* (aspen forest)	VS	SS	VS
4. *Vaccinium membranaceum* (subalpine huckleberry shrubland)	SS	VS	VS
5. *Phyllodoce glanduliflora* (subalpine heath shrubland)	SS	VS	VS
6. *Carex rostrata-C. aquatilis* (sedge marsh)	VS	SS	-
7. *Cassiope mertensiana* (subalpine heath)	SS	VS	SS
8. *Abies lasiocarpa/Luzula hitchcockii* (subalpine fir forest)	SS	SS	SS
9. *Aster alpigenus-Phlox diffusa* (alpine cushion community)	SS	SS	SS
10. *Picea engelmannii/Arnica latifolia* (Engelmann spruce forest)	SS	N	SS
11. *Valeriana sitchensis* (subalpine forb meadow)	SS	N	SS
12. *Picea engelmannii/Thalictrum occidentale* (Engelmann spruce forest)	SS	N	SS
13. *Pseudotsuga menziesii/Symphoricarpos albus* (Douglas-fir forest)	SS	SS	N
14. *Picea glauca/Vaccinium uliginosum* (boreal spruce forest)	SS	—	-
15. *Antennaria lanata-Carex nigricans* (alpine snowbank community)	SS	N	N
16. *Holcus lanatus-Agrostis stolonifera* (acid grassland)	N	SS	-
17. *Deschampsia flexuosa-Holcus lanatus* (acid grassland)	N	SS	-
18. *Xerophyllum tenax* (subalpine beargrass meadow)	N	SS	N
19. *Larix occidentalis/Linnaea borealis* (western larch forest)	N	N	N
20. *Lupinus lepidus-Carex phaeocephala* (alpine stone-stripe community)	N	N	N
21. *Anemone occidentalis-Trollius laxus* (subalpine forb meadow)	N	N	N
22. *Antennaria lanata-Hieracium gracile* (subalpine forb meadow)	N	-	-
23. *Phlox diffusa-Carex phaeocephala* (subalpine cushion community)	N	-	-
24. *Empetrum nigrum* (sand dune heath)	N	N	SR
25. *Arrhenatherum elatius-Holcus lanatus* (neutral grassland)	N	SR	-
26. *Pinus contorta/Vaccinium caespitosum* (lodgepole pine forest)	N	SR	SR
27. *Trollius laxus-Aster foliaceus* (subalpine forb meadow)	N	SR	SR
28. *Luetkea pectinata* (subalpine mat plant community)	N	SR	SR
29. *Calluna vulgaris-Deschampsia flexuosa* (heath-grassland)	SR	N	-
30. *Pinus albicaulis/Vaccinium scoparium* (whitebark pine forest)	SR	N	SR
31. *Arctostaphylos uva-ursi-Carex eburnea* (heath-grassland)	SR	-	-
32. *Dryas octopetala* (alpine cushion community)	SR	SR	VR
33. *Aster alpigenus-Festuca idahoensis* (subalpine meadow)	VR	-	-
34. *Pinus contorta/Xerophyllum tenax* (lodgepole pine forest)	VR	VR	VR
35. *Festuca scabrella-F. idahoensis* (grassland)	VR	VR	VR
36. *Festuca scabrella-Danthonia intermedia* (prairie grassland)	VR	VR	VR
37. *Poa pratensis-Festuca idahoensis* (grassland)	VR	VR	VR
38. *Carex nigricans* (subalpine sedge meadow)	VR	VR	VR

---

[1] Sources are as follows: Nagy and Scotter 1974 (1,2,3,6,8,10,18,27,32,36); Landals and Scotter 1974 (4,7,11,28,38); Landals and Scotter 1973 (5,21); Singer 1971 (9); Schreiner 1980 (14); Bell and Bliss 1973 (15,20); Harrison 1981 (16,17,25,29); Schreiner 1974 (22,23,33); Hylgaard and Liddle 1981 (24); Weaver and Dale 1978 (30,37); Bowles and Maun 1982 (31); Cole 1985c (12,13,19,26,34,35).

[2] The index for resistance to light trampling is the number of passes required to reduce cover to 50 percent of original conditions. Classes are as follows: very susceptible (VS) (0 to 25 passes); somewhat susceptible (SS) (26 to 100 passes); neither susceptible nor resistant (N) (101 to 250 passes); somewhat resistant (SR) (251 to 500 passes); very resistant (VR) (more than 500 passes).

[3] The index for resistance to heavy trampling is relative or percent cover after 800 passes. Classes are as follows: VS (0 to 3 percent); SS (4 to 7 percent); N (8 to 15 percent); SR (16 to 35 percent); VR (more than 35 percent).

[4] The index for both is essentially the mean relative or percent cover across the range from 0 to 800 passes. Classes are as follows: VS (0 to 15 percent); SS (16 to 25 percent); N (26 to 35 percent); SR (36 to 50 percent); VR (more than 50 percent).

The most significant effect of vegetation structure relates to degree of canopy closure. Many studies have observed a tendency for more open communities to be more resistant than closed forests. For example, in a recent study in the Boundary Waters Canoe Area, Marion (1984) found that campsites with 75 to 100 percent tree cover lost 77 percent of their vegetation cover, while sites with 0 to 25 percent tree cover lost only 43 percent. This finding is all the more striking in that vegetation loss did not differ significantly among the seven forested plant communities studied.

This relationship between canopy cover and vegetation impact has a strong theoretical basis. Grime (1979) hypothesized that no plants are well adapted to environments characterized as both high in stress (in this case low light intensity) and high in disturbance. Adaptations to low light intensities make a plant particularly susceptible to trampling damage (Cole 1979). Moreover, the susceptibility of dense forests has been demonstrated in many places—the Pacific Northwest (Schreiner and Moorhead 1979; Cole 1981a), the northern forests (Marion 1984), and the Appalachians (Ripley 1962).

Important soil characteristics that influence amount of impact are soil texture, soil structure, organic matter, moisture, fertility, and depth. Regarding soil textures with the fewest limitations for campsites and trails, Montgomery and Edminster (1966), Epp (1977), and Fay and others (1977) recommend medium-textured soils—sandy loams, fine sandy loams, and loams. Such soils generally have good drainage, are not highly erodible, and have high potential for plant growth. Their major drawback is that their wide range of particle sizes makes them particularly susceptible to compaction (Lull 1959). Coarse soils generally resist water erosion because large particles are neither easily detached nor easily moved. However, their structural instability makes them vulnerable to trail widening and their low water-holding capacity and cation-exchange capacity make them relatively impoverished environments for plant growth. Such drawbacks are likely to be more serious for trails than for campsites. Nevertheless, coarse soils are clearly a better alternative than fine-textured soils. Silts and fine sands are highly erodible because soil particles are both readily detached and moved (Baver 1933). Moreover, silt soils are prone to needle ice formation when wet and become dusty when dry. The permeability of soils high in clay is greatly reduced when compacted. This promotes increased runoff and erosion. Although clay particles resist detachment, they are readily moved by running water. Clays also have little ability to support loads because they deform readily when wet. They are generally sticky when wet and they dry slowly (Leeson 1979).

The role of stones and rocks in soil is complex. Leeson (1979) suggested that they are desirable up to a volume of 25 percent of the soil because they inhibit compaction and increase the resistance of soil particles to entrainment. Above this volume, they make footing difficult and construction and maintenance costly. Bryan (1977) noted that rocks are generally advantageous unless trail degradation has advanced to the point where soil coherence is completely destroyed. Once stones are loose on the trail, rocks increase erosion potential because they increase the turbulence of running water and, when moved, corrode the trail themselves. Summer (1980) suggested not categorically removing stones from trails because this frequently leads to erosion of underlying fines, exposing more rocks. Many of the most severe erosion problems are in stone-free, homogeneous-textured soils (Root and Knapik 1972; Bryan 1977). This textural limitation may explain the problems with trail incision and development of multiple trails in mountain meadows.

Well-developed soil structure promotes drainage; this is generally good. Trampling disrupts structure, particularly when soils are high in clay and when trampling occurs when soils are wet. This loss of structure makes soils more prone to erosion. Generally soils with a granular structure and a high proportion of water-stable aggregates have the fewest limitations for recreational use (Leonard and Plumley 1979). Because trampling destroys both, it is not clear how important these properties are. Soil pans, such as the iron pan described by Bryan (1977), impede drainage and can become more heavily cemented and impenetrable in compacted soils, but, once exposed, their resistance can also serve to inhibit further incision.

The advantages and disadvantages of organic matter are also complex, varying with amount, type, and associated soil characteristics. Organic soils—as opposed to mineral soils—have particularly low bearing strengths when wet. Consequently, they are highly vulnerable to puddling (Bryan 1977) and quickly become wide, muddy quagmires where crossed by trails. Thick surface organic horizons, under forest, shield the mineral soil from compaction (Legg 1973; Marion and Merriam 1985) and inhibit runoff and erosion (Lowdermilk 1930). They also inhibit the germination of most plant species, leading to reduced vegetation cover. Incorporated into the mineral soil, organic matter promotes structural development, which enhances drainage (Leonard and Plumley 1979), inhibits compaction (Dotzenko and others 1967; Marion and Merriam 1985), helps resist dispersion and detachment of soil particles, and promotes plant growth due to its positive influence on water-holding capacity and nutrient availability (Leonard and Plumley 1979).

Soil moisture, as with most other soil parameters, is best in moderate quantities that promote plant growth but do not cause the problems common to poorly drained, wet soils. Moisture decreases the load-bearing capacity of many soils, making them more prone to compaction, puddling, and muddiness problems. Moisture problems are most severe with fine-textured soils and are most likely to cause problems on trails. Moisture also exacerbates the damage inflicted by stock on grazing areas (Strand 1979). Probably a majority of trail problems, in the West at least, result from locating trails in areas that are poorly drained or have high water tables (Root and Knapik 1972). It is often possible to identify vegetational indicators of the soils with high moisture content that are likely to develop muddiness problems unless avoided or bridged (Cole 1983b).

Limited data suggest that vegetation on moderately fertile soils is more resistant than that on highly fertile soils, with vegetation on infertile soils being least tolerant (Ripley 1962; Papamichos 1966; Kellomäki and Saastamoinen 1975; Harrison 1981). There are insufficient data, however, to evaluate how generally applicable or significant such a tendency is.

Finally, deeper soils are often better suited to recreational use than shallow soils (Fay and others 1977). This is primarily a reflection of the erodibility of very shallow soil and the vulnerability of vegetation established in pockets of thin soil. This vulnerability, attributable to very thin soil, is likely to explain the common assumption that mosses are fragile. Mosses, growing on bare rock or in shallow soils, are susceptible to being dislodged. In deep soils, trampling experiments, almost without exception, have shown them to be relatively resistant. The most resistant sites of all are bedrock.

Table 3 summarizes, in very general terms, how these soil properties influence tolerance. Although these general patterns have been identified, much more needs to be learned about how significant these factors are to the maintenance of desirable conditions. The most serious problems, or at least those that have received most attention, occur where trails are located on soils with homogeneous textures (deeply incised, braided trails in meadows) or on wet mineral or organic soils (wide, muddy quagmires).

Locational characteristics include slope steepness and position, topography, aspect, and elevation. On campsites, slopes are generally negligible. On trails, the angle of slope, both along and across the trail, and the position of the trail—close to the top or bottom of a slope—all influence potential for deterioration. These variables all affect the amount and velocity of water running down the trail.

As slope angle along the trail increases, so does erosion potential. Coleman (1981) developed regression models that related path width and depth to the square of the path slope. Her data suggest little problem until slopes exceed 12 to 13 degrees; beyond this, problems increase exponentially. On relatively flat trails, Cole (1983b) found that path depth increased significantly as slope increased, but slope only explained 8 percent of the variation in depth and was not related to path width. Water drainage devices and frequent maintenance can minimize trail problems, even on steep slopes. Moreover, trails with no slope at all have their own problems, primarily a result of poor drainage.

Trails oriented parallel to the slope channel water directly downslope and often deteriorate more dramatically than trails oriented perpendicular to the slope (Bratton and others 1979). Trails located high on slopes have smaller watersheds and, therefore, less erosion potential than trails close to the base of slopes. In valleys covered by complex glacial till deposits, trails near the base of slopes frequently intercept perched water tables (Helgath 1975).

Quite variable results are available for the effect of elevation on site durability. In Great Smoky Mountains National Park, Bratton and others (1978, 1979) reported positive correlations between elevation and both campsite and trail deterioration. Although no data are available, Fay and others (1977), working in the Northeast, suggested that deterioration problems increase with elevation. In the Sierra Nevada, Dykema (1971) found campsite alteration to be greater at both low and high elevations than at moderate elevations. An examination of the tolerance of the plant communities in table 2 shows no relationship between durability and elevation.

The complexity of factors influencing environmental tolerance makes it unlikely for a variable like elevation to relate strongly to tolerance. Perhaps the most consistent effect of increasing elevation is a decrease in length of the growing season. This, along with locally variable factors such as frequent high winds and needle ice, often makes resilience lower at high elevations. Alpine vegetation, for example, is frequently quite resistant (Grabherr 1982 and table 2), but resilience is low. In desert regions, however, higher moisture levels at higher elevations may compensate for a shorter growing season and lead to greater resilience at high elevations. Other characteristics that increase vulnerability and are more common at higher elevations include organic soils, the homogeneous fine-textured soils that are associated with certain types of glacial deposits, areas with poor drainage, and steep trail pitches. Such problems do not increase with elevation in all wildernesses, however, and at almost any elevation sites vary greatly in their level of tolerance.

The effect of aspect is similarly complex. One of the most frequent aspect-related problems occurs high in the mountains, where late snowmelt on northerly aspects contributes to trail widening and erosion through the medium of trampling of water-saturated soils and subsequent channeling of meltwater down the entrenched trail (Price 1981). Under droughty, low-elevation conditions, however, one might expect the more mesic northerly aspects to be more tolerant. In Iowa, Dawson and others

Table 3.—Relationships between soil characteristics and susceptibility to impact

Soil property	Level of susceptibility		
	Low	Moderate	High
Texture	medium	coarse	homogeneous; fine
Organic context	moderate	low	high
Soil moisture	moderate	low	high
Fertility	moderate	high	low
Soil depth	none	deep	shallow

(1974) found that trails on north-facing slopes were less compacted and lost less ground cover than trails on flood plains or south-facing slopes. In northern Utah, vegetation resistance to simulated trampling was greatest on steep northeast slopes, at low elevations (Cieslinski and Wagar 1970). While such generalizations might provide useful guidelines within localized areas, their general utility is questionable.

At the ecosystem level, some have proposed that tolerance increases with primary productivity (Liddle 1975b) and with more advanced successional stages (Goldsmith 1974). Liddle felt that productivity summarized potential for regrowth and the overall hospitality of the environment. Data from five studies generally support the relationship, provided that only the productivity of the ground flora in woodland is considered. However, when quite different physiognomic types are compared, the relationship breaks down. Desert shrub, for example, is notably unproductive and yet it is more resistant to low to moderate levels of recreation use than coniferous forest vegetation (Cole 1983a, 1985b). Perhaps productivity might relate more to resilience than to resistance.

Goldsmith also noted—once he stated that earlier stages in succession were more fragile—that this principle must be qualified by differences in the tolerance of growth forms and by limiting environmental variables. Thus, a seral grassland stage may prove to be more resistant than a climax forest because grasses are more tolerant of trampling than broad-leaved forbs. The theory behind the importance of successional stage stems from the concept that diversity begets stability—that more diverse environments are less susceptible to disturbance. Because later successional stages tend to be diverse, they should be more tolerant of recreational pressure. This concept is generally considered to be an oversimplification and this is certainly true for its application to recreational tolerance. *Carex nigricans* meadows, for example, have low diversity, and yet they are very resistant after soils dry out (table 2).

In sum, it appears that vegetation resistance is probably most highly dependent on the growth form of the constituent species. As this can be highly variable locally, resistance can vary greatly over short distances (Cole 1985c). Resilience, in contrast, is more dependent on environmental factors such as soil fertility, length of the growing season, sunlight levels, and moisture levels. Therefore, it may be possible to demonstrate reduced resilience at higher elevations and with lower primary productivity and diversity. Further work might lead to better theoretical development along these lines.

There is little doubt that an improved understanding of how environmental factors influence impact problems would be tremendously useful to management. By reducing impact through improved site selection, more people can enjoy the wilderness with less impact. Given the complex variables involved and great variability from place to place in the significance of different variables, it is important for wildernesses to develop their own guidelines concerning durable and fragile locations. Many of the best examples of site-specific analysis of impact problems and how they can be avoided are Canadian (for example, Lesko and Robson 1975; Root and Knapik 1972; Landals and Knapik 1972; Landals and Scotter 1974). These studies assess the nature of problems, their causes, how they relate to use and environmental variables, and provide management guidelines to avoid future problems and correct existing problems. In this country, four examples of site-specific research to guide management are: (1) Fay and others' (1977) guidelines for locating and designing overnight facilities in the Northeast, (2) Summer's (1980) ratings of erosion potential and likely trail deterioration problems for major landform units in Rocky Mountain National Park, (3) Cole's (1982a) descriptions of design and locational considerations for major vegetation communities in the Eagle Cap Wilderness, and (4) DeBenedetti and Parsons' (1983) meadow type-specific management recommendations for grazing. Management of most other resources benefits from knowledge about environment variability and its importance to management; wilderness should be no different.

Evaluations of Management Techniques

Remarkably few attempts have been made to evaluate the effectiveness of different techniques that are or could be used to minimize ecological impacts. Few natural experiments have assessed the consequences of management actions that have been taken, and even fewer papers have reviewed existing data and theory for their application to management. This contrasts with the social-psychological side of recreation research where natural experiments have frequently been used to evaluate the effectiveness and acceptability of such techniques as use rationing (Stankey 1979) and the use of information to disperse use (Roggenbuck and Berrier 1981).

Several studies have evaluated the effectiveness of campsite closures as a means of reducing impact. Temporary closures in the Selway-Bitterroot Wilderness were generally ineffective. Little improvement in condition occurred over 8 years of closure. Meanwhile, new campsites developed near the closed ones; after 8 years, deterioration on the new sites was almost as pronounced as on the old sites. Poor success reflected slow natural recovery rates, the lack of assisted recovery, and poor compliance with closures (Cole and Ranz 1983). This suggests that rest-rotation is not a practical means of reducing impact. Slow rates of recovery have also been documented in Sequoia/Kings Canyon National Parks (Parsons and DeBenedetti 1979; Stohlgren 1982).

Limited data from Kings Canyon National Park suggest that implementation of a 1-night length-of-stay limit and a ban on wood fires has reduced campsite damage. One currently little-used site has recovered much of its litter and duff cover and woody fuels following imposition of these regulations (Parsons 1983). Finally, a series of meadow condition assessments, also from Sequoia/Kings Canyon National Parks, demonstrate the effectiveness of a number of actions taken to reduce stock damage (Sumner 1968).

Cole (1981b) reviewed the literature for implications about the likely success of reducing campsite impact through use dispersal and campsite closures. He concluded that dispersal is likely to aggravate impact problems, except in lightly used areas, that temporary closures are seldom effective, and that permanent closures should be evaluated on an individual basis, as opposed to blanket policies such as 200-foot setbacks from water. Craig (1977) advanced his opinions about certain campsite management techniques, recommending containing use to designated sites in heavy-use areas, limiting party size, zoning, hardening sites and providing waste-handling facilities where necessary, and restoring sites. Fay and others (1977) provided a useful summary of location and design criteria for overnight facilities, most applicable to the Northeast. Cole and Dalle-Molle (1982) put together a handbook for planning for and managing campfire impacts.

Trail management is less complex and generally better understood than campsite management. Proper location, design, and maintenance are more important than visitor management (Cole 1983b). Proudman (1977) provided a good summary of how to design, build, and maintain trails in such a way that damage is minimized. In my opinion, little further research on trail management is needed, although individual areas must develop area-specific methods for dealing with their unique situation and problems. This may require correlating trail problems with environmental conditions and monitoring the effectiveness of alternative designs for handling problems (Cole 1983b).

Site Rehabilitation

Significant effort is being expended in attempts to rehabilitate highly impacted backcountry sites. Such efforts are necessary due to the long recovery periods required when recovery is not assisted. A considerable body of information relevant to rehabilitation is accumulating, although it is widely dispersed and most is not directly applicable to wilderness. Perhaps the best initial sources of information on rehabilitation of wilderness sites—although both are now over 5 years old—are Cole and Schreiner's (1981) bibliography and the proceedings of the Recreational Impacts on Wildlands Conference (Ittner and others 1979). A tremendous amount of experience is not being shared because documentation and dissemination of results are poor.

Most of the rehabilitation work in backcountry that has been written up (but not published) is from the Pacific Northwest. Rehabilitation programs at North Cascades, Olympic, and Mount Rainier National Parks have been in the forefront. For this region, considerable progress has been made toward identifying suitable species for either seeding or transplanting (Miller and Miller 1976; Schreiner 1977). Greenhouse propagation techniques for producing transplants have been developed by Miller and Miller (1979). Other papers provide hints about the mechanics of transplanting, from guidelines concerning transplant size to suggestions about watering and fertilization (Miller and Miller 1976; Scott 1977). Two excellent reports (Dalle-Molle 1977; Miller and Miller 1977) discuss how to handle specific problems, such as frost heaving and keeping people off transplants. In the Pacific Northwest, transplanting is generally more successful than seeding, watering is important, and the need for fertilization is questionable and unresolved. One study in the Northeast found fertilization and liming to be ineffective in increasing vegetation cover, although the study's conclusion was to increase amounts, not discontinue the practice (Fay 1975).

One of the few documented experiments testing means of rehabilitating trails occurred on a stretch of multiple trails in Yosemite National Park (Palmer 1979). Of 22 techniques tried, the most successful involved cutting off the sod ridges between trails at the level of the trail tread and stacking them in the shade. The soil beneath both trails and ridges is dug up and sand is added to bring the area up to the level of the surrounding meadow. Finally, the stacked sod is divided into transplant plugs and planted. Considerable progress in rehabilitation could be made if those working with rehabilitation would invest more energy—as Palmer did—in documentation, experimentation, monitoring, and communication of results.

A lot of work was done by Forest Service researchers, in the 1960's particularly, on rehabilitation of developed campgrounds. In several studies involving attempts to establish grass, shrubs, and small trees on campsites in the Southeast, the most conclusive finding was that reducing overstory canopy cover greatly increases grass production (Cordell and Talhelm 1969; Cordell and James 1971; Cordell and others 1974). In Idaho and Utah, watering, seeding, and fertilizing maintained high levels of nonnative grass on campsites (Beardsley and Wagar 1971; Beardsley and others 1974). In Maryland state parks, mulching also contributed to revegetation success (Little and Mohr 1979). All studies stress the overriding importance of designing traffic flow to keep people off vegetated parts of the site.

Research on rehabilitation of nonrecreational sites varies greatly in its applicability to wilderness. Revegetation of high-altitude lands has been addressed in several places—a series of conferences on the topic (such as Kenny 1978), a Forest Service research program focused on the Beartooth Plateau (Brown and others 1978), and a history of work on depleted rangelands (for example, Hull 1974). Such studies help in the identification of factors limiting success, choice of species for rehabilitation, and, to a lesser extent, rehabilitation techniques. Because mining disturbance and rangelands are concentrated in the West, more research is available there than in the East.

Some of the most interesting work is basic research on the factors that limit revegetation success. Perhaps the most notable program here is the work of Marchand and coworkers (Marchand and Roach 1980; Marchand and Sproul 1981; Roach and Marchand 1984) on *Arenaria groenlandica*, *Juncus trifidus*, and *Potentilla tridentata*, common native species found in alpine areas along the Appalachian Trail in New Hampshire. Detailed autecological work has provided more understanding about seed production, dissemination, and germination and the early growth and survival of these species. Major limitations to recolonization by these species are lack of vegetative reproduction, poor seed dissemination, and frequent mortality by frost heaving.

Schreiner (1982) studied the autecology of a native (*Poa incurva*) and a nonnative (*Poa pratensis*) colonizer of disturbed sites. He concluded that traditional site restoration techniques, such as watering and fertilization, would favor *Poa pratensis* at the expense of native species. Research on mycorrhizae is also beginning to reveal their role and importance in rehabilitation (Reeves and others 1979).

The research on revegetation is too extensive to review adequately in several pages. However, much more is needed if we are to increase the cost-effectiveness of the rehabilitation work already underway. The top priority, as mentioned earlier, should be better documentation of what is being done and its success. Major issues that should be addressed include (1) advantages and disadvantages of transplanting versus seeding, (2) the value of scarification, (3) the value of fertilization, (4) the value of and recommendations for mulches, (5) how to reduce frost heaving problems, and (6) whether or not there should be any role for nonnative plants.

In addition, more basic research could improve our understanding of factors that limit the establishment and spread of vegetation. Our poor understanding of the impact process and the importance of documented impacts to ecosystem functioning is a serious problem. We need to understand why many transplants survive year after year, but do not spread. We need to understand more about the importance of mycorrhizae, and we need more autecological studies like those of Marchand and Schreiner.

Impact Monitoring

One final area of research is the development of monitoring systems. Most effort has gone into systems for identifying change on campsites. If replicable, the sampling procedure of any campsite impact study could be the basis of a monitoring system. A number of studies have proposed procedures specific to the task of monitoring, however.

Perhaps the earliest monitoring research was Walker's (1968) exploratory attempt to use panoramic photographs, monoscopic photographs, and stereophotogrammetry. On the basis of his suggestions, 360-degree panoramic photo mosaics, taken from permanent points located near the center of campsites, were incorporated into a monitoring system used by the Selway-Bitterroot Wilderness. While gross changes—fallen trees, new fire rings, and so on—could be identified, it was difficult to identify ground cover changes and any changes beyond the closest trees. Although photographs are unlikely to completely replace the need for field measurements, they can help identify sites for future reassessments, record campsite features not measured in the field, and provide a visual supplement to data collected in the field. Brewer and Berrier (1984) provide useful guidelines for the use of ground-based photography.

In open areas, aerial photography can be used to monitor impacts. Boorman and Fuller (1977) and Price (1981) provided examples of trail deterioration analysis based on air photo interpretation. In Grand Canyon National Park, devegetated trails and camping areas on beaches along the Colorado River have been monitored with large-scale, low-elevation aerial photographs.

Field measurements taken at campsites vary greatly, particularly in level of precision and consumption of time. Hendee and others (1976) proposed a Code-A-Site form for inventory and monitoring. The only site condition information they asked for was an undefined judgment as to whether prior impact had been extreme, heavy, moderate, or light. Some precision was added to this system when managers of the Selway-Bitterroot provided written definitions for these four classes. This was also the approach advanced by Frissell (1978). He proposed a system of five condition classes based on extent of vegetation loss, litter loss, tree root exposure, erosion, and tree mortality.

More elaborate systems have been suggested by Parsons and MacLeod (1980) and Cole (1983c). These systems quickly rate campsites on the basis of such impact parameters as vegetation loss, change in species composition, campsite area, area of barren core, campsite development, campsite cleanliness, loss of organic matter, social trails, tree mutilation, and tree root exposure. Compared to "condition class" systems, these have the advantage of more information, at little additional cost, and disaggregated data on individual impact parameters. Thus, they are more flexible, more generally useful, and more likely to provide insight into exactly how a site is changing over time.

The major alternative to such rapid estimation techniques is a measurement system for campsite area and devegetated area first developed by Schreiner and Moorhead (1979) for use at Olympic National Park. Mount Rainier National Park adapted Schreiner and Moorhead's system of radial measurements to produce reasonably accurate sketch maps to monitor campsite changes. Although quite time consuming, such a system will detect more subtle changes than rapid estimation systems.

Generally, research on campsite monitoring is sufficient for most needs. The next step is transfer of technology and adaptation of existing systems to meet local needs.

TECHNOLOGY TRANSFER

It is difficult to evaluate how extensive technology transfer is—both because it is impossible to keep track of all applications and because it is seldom clear where the idea behind an action came from. The best opportunities for technology transfer are provided in situations where the researcher and the manager have a shared interest in a project and cooperate from the beginning. This situation is most common in the Park Service, although cooperative examples elsewhere do occur. Transfer also becomes easier—or at least is more easily measured—the more tangible the research product. Thus, probably the foremost readily traceable example of successful technology transfer has been the recent spread of campsite monitoring systems.

Following the development of the Code-A-Site form (Hendee and others 1976), quite a few wildernesses inventoried their campsites using the form. Common problems that arose were insufficient information on campsite condition and uncertainty about what to do with the information collected. In Olympic National Park, more relevant information was developed for use with the form and systems for data analysis and periodic reassessments of conditions were developed (Schreiner and Moorhead 1979). Neighboring Mount Rainier National Park borrowed from and modified this innovation.

A compromise between the time-consuming Olympic-Mount Rainier type of system and the low-information Code-A-Site system was developed for use in Sequoia/Kings Canyon National Parks (Parsons and MacLeod 1980). It is also being used in neighboring Yosemite National Park. Cole (1983b) modified the Sequoia/Kings Canyon multiple estimated parameters system by incorporating new parameters, improving estimation techniques, and keeping data disaggregated. Cole's paper also linked the campsite monitoring system to the Limits of Acceptable Change (LAC) planning framework for wilderness management—an attempt to base management on specific objectives (Stankey and others 1985). The combination of a tangible product that is simple to apply, not time consuming, and fulfills a recognized management need led to rapid spread. Within the Forest Service, the Pacific Northwest Region (Oregon and Washington) is adopting the system. It has spread widely in the Northern Rockies (for example, Bob Marshall, Mission Mountains, Rattlesnake, Lee Metcalf, and Frank Church-River of No Return Wildernesses), and a few areas in the Southwest (for example, Superstition Wilderness) are experimenting with it. Through Marion (1984), the system spread first to the Boundary Waters Canoe Area and then to National Park areas along the Delaware River in the East. Through Cole's (1985b) work at Grand Canyon, a similar system is also being applied there.

Another example of successful research application is the management program at Sequoia/Kings Canyon National Parks. This success reflects close cooperation in the Park Service between research and management. At Sequoia/Kings Canyon, management has profited from research on campsite recovery (Parsons and DeBenedetti 1979; Stohlgren 1982), research on meadow condition and response to clipping (DeBenedetti and Parsons 1983), and extensive use of data on use permits and campsite monitoring forms. Particular achievements include a rational use limitation program (Parsons and others 1981), prescription of a variety of actions to deal with problems at a very high-use lake basin (Parsons 1983), and proposal of a comprehensive stock management program (DeBenedetti and Parsons 1983).

Unfortunately, these successes are far outweighed by the lack of research application. Three principal barriers to effective technology transfer are: (1) an adequate research base has not been developed, (2) too little attention has been paid to drawing management implications out of research results, and (3) managers have not always looked to research for solutions to their problems.

Currently, the problem of an insufficient research base is the most serious and basic of these barriers. Without a research base to start with, the other problems are moot. Current allocation of resources between management and research—with very little funding in research—may be adequate for dealing with current "brushfire" problems but is not cost-effective in the long-term because little investment is made in improving future management. The current allocation of recreation management research almost entirely into social research also seems unbalanced. It ignores the primary goal of wilderness management—maintenance of natural conditions—and the fact that ecological impact problems are less reversible than social problems.

The current situation is well illustrated by how resources are being allocated in minimum impact education programs. In 1980, over one-half of all wildernesses were investing management time and funds in such programs (Washburne and Cole 1983), and there are undoubtedly many more areas that now have such programs. Investment in research, both on what to teach and how to teach cost effectively, has been minimal, however. Moreover, what has been done is entirely on **how** to teach rather than **what** to teach—in my view, a classic case of getting the cart before the horse. So now we are in a position of investing scarce wilderness management funds in a curriculum based entirely on personal judgments and opinions (many of them good, I should say). Even a minor investment in what to teach and how to do it would more than pay for itself in little time.

Much of the recreational ecology research that has been done provides little basis for management application. A lack of careers in the field has meant that studies have generally been limited to short-term studies at one place and time. Consequently, results are generally superficial, there is no opportunity to gain the insights that come with experience, and there has been little chance to compare results from a number of places to assess the general applicability of conclusions. This helps explain the lack of theoretical development in the field. Because most studies are done by students at the master's level or as one-time projects, there has been a strong tendency to undertake relatively simple projects generally cut from the same mold. Consequently, we have numerous studies documenting changes in vegetation and soil conditions on recreation sites with little idea of significance.

Designing research so that it is most useful to management is also difficult given the current situation. Cooperation between research and management is limited. Aside from a few Park Service researchers, no agency researchers work in the recreational ecology field. In a few situations, academicians have worked closely with managers (for example, Marion 1984), improving the likelihood of future application, but all too frequently this is not the case. Short-term involvement in the field gives little opportunity for developing the kind of rapport that facilitates the technology transfer process.

Lack of careers also means less attention is given to the management of ecological impacts in recreation management programs in colleges and universities; recreation departments are staffed almost entirely by social scientists. With little training in management of ecological impacts, it is difficult for managers to search effectively for solutions to impact problems. This problem is aggravated by the schedules of most wilderness managers; they are sufficiently busy to preclude much time searching the literature for innovative management solutions.

If careers in recreational ecology were possible, we could build a more substantial research base and improve training of recreation professionals. Over a career, a researcher could gain insights from experience, develop the management implications of research, and build rapport with managers. The challenges of designing research to deal with critical management questions and encouraging the application of results would remain, but the outlook would improve significantly.

RESEARCH GAPS AND FUTURE DIRECTIONS

Problems with maintaining natural vegetation and soil conditions in wilderness are serious. They undermine the intentions of the Wilderness Act and, in many cases, are irreversible. Many impacts are readily obvious even to untrained observers, and simple solutions, such as closing sites to use, are usually available. However, detection of subtle changes and development of innovative solutions that minimize elimination of recreational opportunities and avoid simply moving problems around demand research beyond the "documentation of the obvious" that has characterized the recreational ecology field.

In my opinion, the primary reason for the poor state of the art is lack of support for such research. Despite allocation of almost 90 million acres to wilderness, a land classification with a primary goal of maintaining natural conditions, no continuing program exists in wilderness impact research. Consequently, available research is generally confined to a large number of descriptive studies that lack much time frame, theory, or comparability. Unless support for a critical mass of researchers is forthcoming, there is little to suggest that the current situation will improve appreciably.

To improve, changes need to be made in research design and approach. There is a critical need for more longitudinal studies. The current reliance on cross-sectional studies provides us with a perspective confused by spatial and temporal variability. Cause and effect are difficult to unravel, and there is little to suggest process or the significance of long-term processes. Study periods, for both before-and-after studies and experimental studies, need to be lengthened. Long-term studies will be possible only if researchers have long-term support.

More specialized, detailed studies of the impact process are also needed. Researchers have always had to be "jacks of all trades" to deal with the wide variety of impact problems. Now we need researchers with specialized knowledge, both in subject matter and methodologies. We need to go beyond measurements of soil compaction, for example, to studies of effects on more basic soil properties, such as aeration, micro-organisms, and mycorrhizae. At an even more fundamental level, we need to understand relationships between these altered soil characteristics and plant establishment, growth, and reproduction. Then we will be in a better position to mitigate and rehabilitate impacts.

There is also need for more interdisciplinary approaches. The simultaneous consideration of more elements of the recreational environment would contribute to the development of synergistic insights and more realistic perspectives on management. We need both greater specialization within the natural sciences and more cooperation between natural and social sciences.

We need to expand regional coverage to parts of the country that have seldom been studied (almost any place other than the Sierra Nevada, Pacific Northwest, Northern Rockies, and Boundary Waters Canoe Area). Some of this research needs to be designed to be comparable with studies undertaken elsewhere. This would improve our current ability to assess the general applicability of research results. Other research should remain site specific. A good example would be research, modeled after the grazing research at Sequoia/Kings Canyon National Parks, to develop similar grazing management programs adapted to the unique situation of the area where the research is being done.

Many topics stand out as high-priority research needs. We clearly need an improved knowledge of wilderness ecosystems and their dynamics. This is important from the standpoint of evaluating our actions outside wilderness as well as improving wilderness management. Such information is important to the wilderness manager as a planning tool for evaluating likely consequences of management actions and as a picture of baseline conditions to be maintained.

Another major research need is information to improve management of both recreational and nonrecreational grazing. Neither is well understood within the context of an area with nature conservation goals like wilderness. Although both are permitted uses that detract from certain management goals, such conflicts can be minimized through research designed to tailor management to a given use and environmental situation. The Sequoia/Kings Canyon program (DeBenedetti and Parsons 1983) provides a good recreational grazing example, but no comparable domestic livestock example exists.

Along the lines of more traditional recreational ecology, top priorities include identification of use/impact relationships for varied ecosystem types, improved campsite design and/or maintenance practices, improved site rehabilitation techniques, improved recommendations for minimum impact camping, and more evaluation of management practices. Improved understanding of use/impact relationships could help identify use thresholds above which impacts become unacceptable. This information is needed to decide between requiring use of designated sites and allowing at-large camping, to impose use limits, and to attempt to direct use to resistant sites. This is particularly important in managing impacts in low-use portions of wildernesses where management emphasis is on dispersal and low-impact use.

Where use is concentrated on a few designated high-impact sites, design and maintenance techniques are needed to channel use and avoid site expansion. "Inter-site zones" need to be created and maintained, to be used as nurseries to replace overstory trees as they die. Experimentation with means of doing this should be a high priority. Improvement of site rehabilitation techniques is a closely related research topic. It is not clear, at this point, how much of this work can be generally applicable and how much is site specific or how much should be done by researchers as opposed to managers. What is clear is that we need both general and site-specific work and improved cooperation and communication between researchers and managers as well as between managers of different wildernesses.

I have mentioned the need for research on appropriate minimum-impact techniques a number of times in this paper. Although the value of recommendations such as not cutting down trees cannot be questioned, the advisability of certain fire building techniques is debatable. Moreover, the appropriateness of techniques varies between environments and between high-use and low-use situations. Improved knowledge, through research, could avoid problems of recommending inappropriate behavior and could tailor user behavior to different situations.

Finally, we should take advantage of the countless natural experiments that are taking place whenever management or use patterns change. We need to monitor change and evaluate the effectiveness of alternative techniques for minimizing impact.

The ultimate payoff of recreational ecology research to management is in efficient achievement of objectives. Impacts will never be eliminated, but both their distribution and their severity can be controlled and kept within acceptable limits. Actions taken to achieve objectives can be tailored to particular use and environmental situations that vary throughout the wilderness. To do this, however, we will need to finally make a serious investment in recreational ecology research, as we have in most other resource management disciplines.

REFERENCES

Armstrong, J. E. A study of grazing conditions in the Roaring River District, Kings Canyon National Park, with recommendations. 1942. Unpublished paper on file at: U.S. Department of the Interior, National Park Service, Sequoia and Kings Canyon National Parks, Three Rivers, CA. 177 p.

Bates, G. H. The vegetation of footpaths, sidewalks, carttracks and gateways. Journal of Ecology. 23: 470-487; 1935.

Baver, L. D. Some soil factors affecting erosion. Agricultural Engineering. 14(2): 51-52; 1933.

Bayfield, N. Some effects of walking and skiing on vegetation at Cairngorm. In: Duffey, E.; Watt, A. S., eds. The scientific management of animal and plant communities for conservation. Oxford: Blackwell Scientific Publications; 1971: 469-485.

Bayfield, N. G. Use and deterioration of some Scottish hill paths. Journal of Applied Ecology. 10: 635-644; 1973.

Bayfield, N. G. Recovery of four montane heath communities on Cairngorm, Scotland, from disturbance by trampling. Biological Conservation. 15: 165-179; 1979.

Bayfield, N. G. Effects of extended use on footpaths in mountain areas of Britain. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological effects of outdoor recreation on mountain areas in Europe and North America. Recreation Ecology Research Group Report No. 9; 1985: 100-111. [Available from Shirley Wright, Department of Horticulture, Wye College, Wye, Ashford, Kent, United Kingdom.]

Beardsley, W. G.; Wagar, J. A. Vegetation management on a forested recreation site. Journal of Forestry. 69: 728-731; 1971.

Beardsley, W. G.; Herrington, R. B.; Wagar, J. A. Recreation site management: how to rehabilitate a heavily used campground without stopping visitor use. Journal of Forestry. 72: 279-281; 1974.

Blom, C. W. P. M. Effects of trampling and soil compaction on the occurrence of some *Plantago* species in coastal sand dunes. I. Soil compaction, soil moisture and seedling emergence. Oecologica Plantarum. 11: 225-241; 1976.

Blom, C. W. P. M. Effects of trampling and soil compaction on the occurrence of some *Plantago* species in coastal sand dunes. II. Trampling and seedling establishment. Oecologica Plantarum. 12: 363-381; 1977.

Boomsma, J. J.; van der Ploeg, S. W. F. Effects of three-year experimental trampling on a dune valley. Part I: Effects of trampling during one season. Working Paper 68. Amsterdam: Institute for Environmental Studies, Free University; 1976. 34 p.

Boorman, L. A.; Fuller, R. M. Studies on the impact of paths on the dune vegetation at Winterton, Norfolk, England. Biological Conservation. 12: 203-216; 1977.

Bowles, J. M.; Maun, M. A. A study of the effects of trampling on the vegetation of Lake Huron sand dunes at Pinery Provincial Park. Biological Conservation. 24: 273-283; 1982.

Bratton, S. P. Effects of disturbance by visitors on two woodland orchid species in Great Smoky Mountains National Park, USA. Biological Conservation. 31: 211-227; 1985.

Bratton, S. P.; Hickler, M. G.; Graves, J. H. Visitor impact on backcountry campsites in the Great Smoky Mountains. Environmental Management. 2: 431-442; 1978.

Bratton, S. P.; Hickler, M. G.; Graves, J. H. Trail erosion patterns in Great Smoky Mountains National Park. Environmental Management. 3: 431-445; 1979.

Bratton, S. P.; Stromberg, L. L.; Harmon, M. E. Firewood-gathering impacts in backcountry campsites in Great Smoky Mountains National Park. Environmental Management. 6: 63-71; 1982.

Brewer, L.; Berrier, D. Photographic techniques for monitoring resource change at backcountry sites. General Technical Report NE-86. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1984. 13 p.

Brockman, C. F. Ecological study of subalpine meadows, Paradise Valley Area, Mount Rainier National Park, Washington. 1959. Unpublished report on file at: U.S.

Department of the Interior, National Park Service, Mount Rainier National Park, WA. 83 p.

Brown, J. H., Jr.; Kalisz, S. P.; Wright, W. R. Effects of recreational use on forested sites. Environmental Geology. 1: 425-431; 1977.

Brown, R. W.; Johnston, R. S.; Johnson, D. A. Rehabilitation of alpine tundra disturbances. Journal of Soil and Water Conservation. 33: 154-160; 1978.

Bryan, R. B. The influence of soil properties on degradation of mountain hiking trails at Grövelsjön. Geografiska Annaler. 59A(1-2): 49-65; 1977.

Burden, R. F.; Randerson, P. F. Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. Journal of Applied Ecology. 9: 439-457; 1972.

Carothers, S. W.; Aitchison, S. W., eds. An ecological survey of the riparian zone of the Colorado River between Lee's Ferry and the Grand Wash Cliffs. Technical Report 10. Grand Canyon National Park, AZ: U.S. Department of the Interior, National Park Service, Grand Canyon National Park; 1976. 251 p.

Cieslinski, T. J.; Wagar, J. A. Predicting the durability of forest recreation sites in northern Utah—preliminary results. Research Note INT-117. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1970. 7 p.

Cobb, F.; Stark, R. Decline and mortality of smog-injured ponderosa pine. Journal of Forestry. 68: 147-149; 1970.

Cole, D. N. Man's impact on wilderness vegetation: an example from Eagle Cap Wilderness, northeastern Oregon. Eugene, OR: University of Oregon; 1977. 307 p. Dissertation.

Cole, D. N. Estimating the susceptibility of wildland vegetation to trailside alteration. Journal of Applied Ecology. 15: 281-286; 1978.

Cole, D. N. Reducing the impact of hikers on vegetation: an application of analytical research methods. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 71-78.

Cole, D. N. Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness, Oregon: some management implications. Biological Conservation. 20: 247-270; 1981a.

Cole, D. N. Managing ecological impacts at wilderness campsites: an evaluation of techniques. Journal of Forestry. 79: 86-89; 1981b.

Cole, D. N. Vegetation of two drainages in Eagle Cap Wilderness, Wallowa Mountains, Oregon. Research Paper INT-288. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982a. 42 p.

Cole, D. N. Wilderness campsite impacts: effect of amount of use. Research Paper INT-284. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982b. 34 p.

Cole, D. N. Controlling the spread of campsites at popular wilderness destinations. Journal of Soil and Water Conservation. 37: 291-295; 1982c.

Cole, D. N. Campsite conditions in the Bob Marshall Wilderness, Montana. Research Paper INT-312. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983a. 18 p.

Cole, D. N. Assessing and monitoring backcountry trail conditions. Research Paper INT-303. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983b. 10 p.

Cole, D. N. Monitoring the condition of wilderness campsites. Research Paper INT-302. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983c. 10 p.

Cole, D. N. Management of ecological impacts in wilderness areas in the United States. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological impacts of outdoor recreation on mountain areas in Europe and North America. Recreation Ecology Research Group Report No. 9; 1985a: 138-154. [Available from Shirley Wright, Department of Horticulture, Wye College, Wye, Ashford, Kent, United Kingdom.]

Cole, D. N. Ecological impacts on backcountry campsites in Grand Canyon National Park. 1985b. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Grand Canyon National Park, AZ. 96 p.

Cole, D. N. Recreational trampling effects on six habitat types in western Montana. Research Paper INT-350. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985c. 43 p.

Cole, D. N.; Benedict, J. Wilderness campsite selection—what should users be told? Park Science. 3(4): 5-7; 1983.

Cole, D. N.; Dalle-Molle, J. Managing campfire impacts in the backcountry. General Technical Report INT-135. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 16 p.

Cole, D. N.; Fichtler, R. K. Campsite impact in three western wilderness areas. Environmental Management. 7: 275-286; 1983.

Cole, D. N.; Ranz, B. Temporary campsite closures in the Selway-Bitterroot Wilderness. Journal of Forestry. 81: 729-732; 1983.

Cole, D. N.; Schreiner, E. G. S. Impacts of backcountry recreation: site management and rehabilitation—an annotated bibliography. General Technical Report INT-121. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 58 p.

Coleman, R. Footpath erosion in the English Lake District. Applied Geography. 1: 121-131; 1981.

Coombs, E. A. K. The impacts of camping on vegetation in the Bighorn Crags, Idaho Primitive Area. Moscow, ID: University of Idaho; 1976. 63 p. Thesis.

Cordell, H. K.; James, G. A. Supplementing vegetation on southern Appalachian recreation sites with small trees and shrubs. Journal of Soil and Water Conservation. 26: 235-238; 1971.

Cordell, H. K.; James, G. A.; Tyre, G. L. Grass establishment on developed recreation sites. Journal of Soil and Water Conservation. 29: 268-271; 1974.

Cordell, H. K.; Talhelm, D. R. Planting grass appears impractical for improving deteriorated recreation sites. Research Note SE-105. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1969. 2 p.

Craig, W. S. Reducing impacts from river recreation users. In: Proceedings, river recreation management research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 155-162.

Crawford, A. K.; Liddle, M. J. The effect of trampling on neutral grassland. Biological Conservation. 12: 135-142; 1977.

Dale, D.; Weaver, T. Trampling effects on vegetation of the trail corridors of north Rocky Mountain forests. Journal of Applied Ecology. 11: 767-772; 1974.

Dalle-Molle, J. Resource restoration. 1977. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Mount Rainier National Park, Longmire, WA. 19 p.

Davilla, B. Firewood production, use, and availability in the High Sierra. In: Stanley, J. T., Jr.; Harvey, H. T.; Hartesveldt, R. J., eds. A report on the wilderness impact study: the effects of human recreational activities on wilderness ecosystems with special emphasis on Sierra Club wilderness outings in the Sierra Nevada. San Francisco: Sierra Club; 1979: 94-128.

Dawson, J. O.; Countryman, D. W.; Fittin, R. R. Soil and vegetative patterns in northeastern Iowa campgrounds. Journal of Soil and Water Conservation. 33: 39-41; 1978.

Dawson, J. O.; Hinz, P. N.; Gordon, J. C. Hiking trail impact on Iowa stream valley forest preserves. Iowa State Journal of Research. 48: 329-337; 1974.

DeBenedetti, S. H.; Parsons, D. J. Protecting mountain meadows: a grazing management plan. Parks. 8(3): 11-13; 1983.

del Moral, R. Predicting human impact on high elevation ecosystems. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 292-303.

Donard, G. B.; Cook, C. W. Carbohydrate reserve content of mountain range plants following defoliation and regrowth. Journal of Range Management. 23: 15-19; 1970.

Dotzenko, A. D.; Papamichos, N. T.; Romine, D. S. Effects of recreational use on soil and moisture conditions in Rocky Mountain National Park. Journal of Soil and Water Conservation. 22: 196-197; 1967.

Douglas, G. W.; Nagy, J. A. S.; Scotter, G. W. Effects of human and horse trampling on natural vegetation, Waterton Lakes National Park. 1975. Unpublished report on file at: Canadian Wildlife Service, Edmonton, AB. 129 p.

Duffey, E., ed. The biotic effects of public pressure on the environment. Monks Wood Experiment Station Symposium 3. Huntingdon, England: Nature Conservancy; 1967. 178 p.

Dunn, B. A.; Lockaby, B. G.; Johnson, E. E. Camping and its relationship to forest soil and vegetation properties in South Carolina. Forest Research Series No. 34. Clemson, SC: Clemson University; 1980. 20 p.

Dykema, J. A. Ecological impact of camping upon the southern Sierra Nevada. Los Angeles: University of California; 1971. 156 p. Dissertation.

Echelberger, H. E. Vegetation changes at Adirondack campgrounds—1964 to 1969. Research Note NE-142. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1971. 8 p.

Edwards, I. J. The ecological impact of pedestrian traffic on alpine vegetation in Kosciusko National Park. Australian Forestry. 40: 108-120; 1977.

Edwards, O. M. Vegetation disturbance by natural factors and visitor impact in the alpine zone of Mount Rainier National Park: implications for management. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 101-106.

Emanuelsson, U. A method for measuring trampling effects on vegetation ("the circle sector method"). In: The use of ecological variables in environmental monitoring: First Nordic Oikas conference; 1978 October 2-4; Uppsala, Sweden. Report PM 1151. National Swedish Environment Protection Board; 1979: 91-94.

Emanuelsson, U. Recreation impact on mountain areas in northern Sweden. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological impacts of recreation on mountain areas in Europe and North America. Recreation Ecology Research Group Report No. 9; 1985: 63-73. [Available from Shirley Wright, Department of Horticulture, Wye College, Wye, Ashford, Kent, United Kingdom.]

Epp, P. F. Guidelines for assessing soil limitations for trails in the Southern Canadian Rockies. Edmonton, AB: University of Alberta; 1977. 164 p. Thesis.

Falínski, J. B. Die reaktion der waldbodenvegetation auf trittwirkung im lichte experimenteller forschungen. Phytocoenologia. 2: 451-465; 1975.

Fay, S. Ground-cover vegetation management at backcountry recreation sites. Research Note NE-201. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1975. 5 p.

Fay, S. C.; Rice, S. K.; Berg, S. P. Guidelines for design and location of overnight backcountry facilities. 1977. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Broomall, PA. 23 p.

Fazio, J. R. Communicating with the wilderness user. Bulletin 28. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1979. 65 p.

Fenn, D. B.; Gogue, G. J.; Burge, R. E. Effects of campfires on soil properties. Ecological Services Bulletin, Number 5. Washington, DC: U.S. Department of the Interior, National Park Service; 1976. 16 p.

Fichtler, R. K. The relationship of recreational impacts on backcountry campsites to selected Montana habitat types. Missoula, MT: University of Montana; 1980. 109 p. Thesis.

Fish, E. B.; Brothers, G. L.; Lewis, R. B. Erosional impacts of trails in Guadalupe Mountains National Park, Texas. Landscape Planning. 8: 387-398; 1981.

Fletcher, N.; Shaver, G. R. Life histories of tillers of *Eriophorum vaginatum* in relation to tundra disturbance. Journal of Ecology. 71: 131-147; 1983.

Foin, T. C., Jr., ed. Visitor impacts on national parks: the Yosemite ecological impact study. Institute of Ecology Publication 10. Davis, CA: University of California; 1977. 99 p.

Franklin, J. F. Wilderness ecosystems. In: Hendee, J. C.; Stankey, G. H.; Lucas, R. C. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 191-214.

Franklin, J. F.; Swanson, F. J.; Sedell, J. R. Relationships within the valley floor ecosystems in western Olympic National Park: a summary. In: Starkey, E. E.; Franklin, J. F.; Matthews, J. W., eds. Ecological research in National Parks of the Pacific Northwest. Corvallis, OR: U.S. Department of the Interior, National Park Service, Cooperative Park Studies Unit; 1982: 43-45.

Frissell, S. S. The impact of wilderness visitors on natural ecosystems. 1973. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Missoula, MT. 60 p.

Frissell, S. S. Judging recreation impacts on wilderness campsites. Journal of Forestry. 76: 481-483; 1978.

Frissell, S. S., Jr.; Duncan, D. P. Campsite preference and deterioration in the Quetico-Superior canoe country. Journal of Forestry. 65: 256-260; 1965.

Godin, V. B.; Leonard, R. E. Management problems in designated wilderness areas. Journal of Soil and Water Conservation. 34: 141-143; 1979.

Goldsmith, F. B. Ecological effects of visitors in the countryside. In: Warren, A.; Goldsmith, F. B., eds. Conservation practice. London: John Wiley and Sons; 1974: 217-232.

Goldsmith, F. B.; Munton, R. J. C.; Warren, A. The impact of recreation on the ecology and amenity of seminatural areas: methods of investigation used in the Isles of Scilly. Biological Journal of the Linnaean Society. 2: 287-306; 1970.

Goryshina, T. K. Effect of trampling during recreational loads on internal leaf and thallome structure in certain plants. Soviet Journal of Ecology. 14: 192-198; 1983.

Grabherr, G. The impact of trampling by tourists on a high altitudinal grassland in the Tyrolean Alps, Austria. Vegetatio. 48: 209-219; 1982.

Grime, J. P. Plant strategies and vegetation processes. New York: John Wiley and Sons; 1979. 222 p.

Harper, J. L.; Williams, J. T.; Sagar, G. R. The behavior of seeds in soil. I. The heterogeneity of soil surfaces and its role in determining the establishment of plants from seed. Journal of Ecology. 53: 273-286; 1965.

Harrison, C. Recovery of lowland grassland and heathland in southern England from disturbance by seasonal trampling. Biological Conservation. 19: 119-130; 1981.

Hart, J. B., Jr. Ecological effects of recreation use on campsites. In: Countryman, D. W.; Sofranko, D. M., eds. Guiding land use decisions: planning and management for forests and recreation. Baltimore, MD: Johns Hopkins University Press; 1982: 150-182.

Hartesveldt, R. J. The effects of human impacts on *Sequoia gigantea* and its environment in the Mariposa Grove, Yosemite National Park, California. Ann Arbor, MI: University of Michigan; 1963. 310 p. Dissertation.

Hartley, E. A. Man's effects on the stability of alpine and subalpine vegetation in Glacier National Park, Montana. Durham, NC: Duke University; 1976. 258 p. Dissertation.

Harvey, A. E.; Jurgensen, M. F.; Larsen, M. J. Role of forest fuels in the biology and management of soil. General Technical Report INT-65. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 8 p.

Hecht, S. B. Ecological carrying capacity research, Yosemite National Park. Part II. Human impact on subalpine ecosystems: microclimate. PB-270-956. Washington, DC: U.S. Department of Commerce, National Technical Information Center; 1976. 27 p.

Helgath, S. F. Trail deterioration in the Selway-Bitterroot Wilderness. Research Note INT-193. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 15 p.

Hendee, J. C.; Clark, R. N.; Hogans, M. L.; [and others.] Code-A-Site: a system for inventory of dispersed recreational sites in roaded areas, backcountry, and wilderness. Research Paper PNW-209. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 33 p.

Hinds, T. E. Aspen mortality in Rocky Mountain campgrounds. Research Paper RM-164. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1976. 20 p.

Holmes, D. O.; Dobson, H. E. M. Ecological carrying capacity research: Yosemite National Park. Part I. The effects of human trampling and urine on subalpine vegetation, a survey of past and present backcountry use, and the ecological carrying capacity of wilderness. PB-270-955. Washington, DC: U.S. Department of Commerce, National Technical Information Center; 1976. 247 p.

Hull, A. C., Jr. Seedling emergence and survival from different seasons and rates of seeding mountain rangelands. Journal of Range Management. 27: 302-304; 1974.

Hylgaard, T.; Liddle, M. J. The effect of human trampling on a sand dune ecosystem dominated by *Empetrum nigrum*. Journal of Applied Ecology. 18: 559-569; 1981.

International Union for the Conservation of Nature and Natural Resources. Towards a new relationship of man and nature in temperate lands. Part I. Ecological impact of recreation and tourism upon temperate environments. New Series No. 7, Part I. Morges, Switzerland: International Union for the Conservation of Nature and Natural Resources; 1967. 287 p.

Ittner, R.; Potter, D. R.; Agee, J. K.; Anschell, S., eds. Proceedings: recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979. 333 p.

James, T. D. W.; Smith, D. W.; Mackintosh, E. E.; [and others]. Effects of camping recreation on soil, jack pine and understory vegetation in a northwestern Ontario park. Forest Science. 25: 333-349; 1979.

Jerry, D. G. Impact of boaters on river campgrounds in Dinosaur National Monument. Fort Collins, CO: Colorado State University; 1977. Thesis.

Johnson, D. W.; Hinds, T. E. Aspen mortality at the Maroon Lake Campground. Biological evaluation. R2-77-21. Lakewood, CO: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Forest Insect and Disease Management; 1977. 18 p.

Jollif, G. D. Campground site-vegetation relationships. Fort Collins, CO: Colorado State University; 1969. 139 p.

Jones, D. H. The effect of pedestrian impact on selected soils. Glasgow, Scotland: University of Glasgow; 1978. 154 p. Thesis.

Karnosky, D. F. Dutch elm disease: a review of the history, environmental implications, control, and research needs. Environmental Conservation. 6: 311-322; 1979.

Kazanskaya, N. S. Forests near Moscow as territories of mass recreation and tourism. Urban Ecology. 2: 371-395; 1977.

Kellomäki, S. Deterioration of forest ground cover during trampling. Silva Fennica. 11: 153-161; 1977.

Kellomäki, S.; Saastamoinen, V. L. Trampling tolerance of forest vegetation. Acta Forestalia Fennica. 147: 5-19; 1975.

Kenny, S. T., ed. Proceedings: revegetation of high-altitude disturbed lands workshop. Environmental Resources Center Information Series 28. Fort Collins, CO: University of Colorado; 1978. 213 p.

Ketchledge, E. H.; Leonard, R. E. The impact of man on the Adirondack high country. The Conservationist. 25(2): 14-18; 1970.

Kuss, F. R. Hiking boot impacts on woodland trails. Journal of Soil and Water Conservation. 38: 119-121; 1983.

Kuss, F. R.; Morgan, J. M., III. Estimating the physical carrying capacity of recreation areas: a rationale for application of the universal soil loss equation. Journal of Soil and Water Conservation. 35: 87-89; 1980.

Kuss, F. R.; Morgan, J. M., III. Using the USLE to estimate the physical carrying capacity of natural areas for outdoor recreation planning. Journal of Soil and Water Conservation. 39: 383-387; 1984.

Kuss, F. R.; Vaske, J.; Graefe, A. A review and synthesis of recreational carrying capacity literature. Final report to: National Parks and Conservation Association, Washington, DC. 1985. 210 p.

Laing, C. C. A report on the effect of visitors on the natural landscape in the vicinity of Lake Solitude, Grand Teton National Park, Wyoming. 1961. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Grand Teton National Park, WY. 62 p.

Landals, A. G.; Knapik, L. J. Great Divide Trail: an ecological study of the proposed route, Jasper National Park and vicinity. 1972. Unpublished report on file at: Canadian Wildlife Service, Edmonton, AB. 251 p.

Landals, M.; Scotter, G. W. Visitor impact on meadows near Lake O'Hara, Yoho National Park. 1973. Unpublished report on file at: Canadian Wildlife Service, Edmonton, AB. 184 p.

Landals, M.; Scotter, G. W. An ecological assessment of the Summit Area, Mount Revelstoke National Park. 1974. Unpublished report on file at: Canadian Wildlife Service, Edmonton, AB. 197 p.

LaPage, W. F. Recreation and the forest site. Journal of Forestry. 60: 319-321; 1962.

LaPage, W. F. Some observations on campground trampling and groundcover response. Research Paper NE-68. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1967. 11 p.

Leeson, B. F. Research on wildland recreation impact in the Canadian Rockies. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 64-65.

Legg, M. Site factors useful in predicting deterioration of forest campsites in northern Michigan. East Lansing, MI: Michigan State University; 1973. 99 p. Dissertation.

Legg, M. H.; Schneider, G. Soil deterioration on campsites: northern forest types. Soil Science Society of America Journal. 41: 437-441; 1977.

Lemons, J. Visitor use impact in a subalpine meadow, Yosemite National Park, California. In: Linn, R. M., ed. Proceedings, conference on scientific research in the National Parks. Transactions and Proceedings Series, Number 5. Washington, DC: U.S. Department of the Interior, National Park Service; 1979: 1287-1292.

Leney, F. M. The ecological effects of public pressure on picnic sites. Journal of the Sports Turf Research Institute. 50: 47-51; 1974.

Leonard, R. E.; Plumley, H. The use of soils information for dispersed recreation planning. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 50-63.

Leonard, R. E.; Whitney, A. M. Trail transect: a method for documenting trail changes. Research Paper NE-389. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p.

Leonard, R. E.; McBride, J. M.; Conkling, P. W.; McMahon, J. L. Ground cover changes resulting from low-level camping stress on a remote site. Research Paper NE-530. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 4 p.

Leonard, R. E.; McMahon, J. L.; Kehoe, K. M. Hiker trampling impacts on eastern forests. Research Paper NE-555. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 5 p.

Lesko, G. L.; Robson, E. B. Impact study and management recommendations for primitive campgrounds in the Sunshine-Egypt Lake Area, Banff National Park. Information Report NOR-X-132. Edmonton, AB: Northern Forest Research Centre; 1975. 86 p.

Liddle, M. J. A selective review of the ecological effects of human trampling on natural ecosystems. Biological Conservation. 7: 17-36; 1975a.

Liddle, M. J. A theoretical relationship between the primary productivity of vegetation and its ability to tolerate trampling. Biological Conservation. 8: 251-255; 1975b.

Liddle, M. J.; Greig-Smith, P. A survey of tracks and paths in a sand dune ecosystem. Journal of Applied Ecology. 12: 893-930; 1975.

Little, S.; Mohr, J. J. Reestablishing understory plants in overused wooded areas of Maryland state parks. Research Paper NE-431. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1979. 9 p.

Lowdermilk, W. C. Influence of forest litter on runoff, percolation and erosion. Journal of Forestry. 28: 474-491; 1930.

Lucas, R. C. Trends in wilderness use patterns, visitor characteristics, and attitudes in the Bob Marshall Wilderness complex. Research Paper INT-345. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 32 p.

Lull, H. W. Soil compaction on forest and range lands. Miscellaneous Publication 768. Washington, DC: U.S. Department of Agriculture, Forest Service; 1959. 33 p.

Lutz, H. J. Soil conditions of picnic grounds in public forest parks. Journal of Forestry. 43: 121-127; 1945.

Magill, A. W. Five California campgrounds . . . conditions improve after five years' recreational use. Research Paper PSW-62. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1970. 18 p.

Magill, A. W.; Nord, E. C. An evaluation of campground conditions and needs for research. Research Note PSW-4. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1963. 8 p.

Malin, L.; Parker, A. Z. Ecological carrying capacity research: Yosemite National Park. Part III. Subalpine soils and wilderness use. PB-27-957. Washington, DC: U.S. Department of Commerce, National Technical Information Center; 1976. 89 p.

Manning, R. E. Impacts of recreation on riparian soils and vegetation. Water Resources Bulletin. 15: 30-43; 1979.

Marchand, P. J.; Roach, D. A. Reproductive strategies of pioneering alpine species: seed production, dispersal, and germination. Arctic and Alpine Research. 12: 137-146; 1980.

Marchand, P. J.; Sproul, G. D. Colonization of disturbed alpine sites by *Arenaria groenlandica*, White Mountains, New Hampshire, USA. A stochastic model. Mountain Research and Development. 1: 281-286; 1981.

Marion, J. L. Ecological changes resulting from recreational use: a study of backcountry campsites in the Boundary Waters Canoe Area, Minnesota. St. Paul, MN: University of Minnesota; 1984. 279 p. Dissertation.

Marion, J. L.; Merriam, L. C. Predictability of recreational impact on soils. Soil Science Society of America Journal. 49: 751-753; 1985.

Marnell, L.; Foster, D.; Chilman, K. River recreation research conducted at Ozark National Scenic Riverways 1970-1977: a summary of research projects and findings. Van Buren, MO: U.S. Department of the Interior, National Park Service; 1978. 139 p.

Marshall, E. The summer of the gypsy moth. Science. 213: 991-993; 1981.

McCool, S. F.; Merriam, L. C., Jr; Cushwa, C. T. The condition of wilderness campsites in the Boundary Waters Canoe Area. Minnesota Forestry Research Note 202. St. Paul, MN: University of Minnesota; 1969. 4 p.

McEwen, D.; Tocher, S. R. Zone management: key to controlling recreational impact in developed campsites. Journal of Forestry. 74: 90-93; 1976.

McQuaid-Cook, J. Effects of hikers and horses on mountain trails. Journal of Environmental Management. 6: 209-212; 1978.

Meinecke, E. P. The effect of excessive tourist travel on the California redwood parks. Sacramento, CA: California Department of Natural Resources, Division of Parks; 1928. 20 p.

Merkle, J. Ecological studies of the Amphitheater and Surprise Lakes cirque in the Teton Mountains, Wyoming. 1963. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Grand Teton National Park, WY. 25 p.

Merriam, L. C.; Peterson, R. F. Impact of 15 years of use on some campsites in the Boundary Waters Canoe Area. Minnesota Forestry Research Note 282. St. Paul, MN: University of Minnesota; 1983. 3 p.

Merriam, L. C., Jr.; Smith, C. K. Newly established campsites in the BWCA, restudy of selected sites—1974. Minnesota Forestry Research Note 254. St. Paul, MN: University of Minnesota; 1975. 4 p.

Merriam, L. C., Jr.; Smith, C. K.; Miller, D. E.; [and others]. Newly developed campsites in the Boundary Waters Canoe Area—a study of five years' use. Bulletin 511. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1973. 27 p.

Miller, J. W.; Miller, M. M. Revegetation in the subalpine zone. University of Washington Arboretum Bulletin. 39(4): 12-16; 1976.

Miller, J. W.; Miller, M. M. Propagation of plant material for subalpine revegetation. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29. Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 304-310.

Miller, M. M.; Miller, J. W. Suggested revegetation practices. 1977. Unpublished report on file at: U.S. Department of the Interior, National Park Service, North Cascades National Park, Sedro Woolley, WA. 13 p.

Moir, W. H.; Hobson, F. D.; Hemstrom, M.; Franklin, J. Forest ecosystems of Mount Rainier National Park. In: Linn, R. M., ed. Proceedings, first conference on scientific research in the National Parks. Transactions and Proceedings Series, Number 5. Washington, DC: U.S. Department of the Interior, National Park Service; 1979: 201-208.

Montgomery, P. H.; Edminster, F. C. Use of soil surveys in planning for recreation. In: Bartell, L. J., ed. Soil surveys and land use planning. Madison, WI: Soil Science Society of America and American Society of Agronomy; 1966: 104-112.

Monti, P.; Mackintosh, E. E. Effect of camping on surface soil properties in the boreal forest region of northwestern Ontario, Canada. Soil Science Society of America Journal. 43: 1024-1029; 1979.

Morgan, R. P. C. The impact of recreation on mountain soils: towards a predictive model for soil erosion. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological effects of outdoor recreation on mountain areas in Europe and North America. Recreation Ecology Research Group Report No. 9; 1985: 112-121. [Available from Shirley Wright, Department of Horticulture, Wye College, Wye, Ashford, Kent, United Kingdom.]

Munton, R. J. C. Ecosystem function and recreational activity: the question of scale. Don [Journal of the Sheffield University Geographical Society]. 15: 33-39; 1972.

Nagy, J. A. S.; Scotter, G. W. A quantitative assessment of the effects of human and horse trampling on natural areas, Waterton Lakes National Park. 1974. Unpublished report on file at: Canadian Wildlife Service, Edmonton, AB. 145 p.

Palmer, R. Progress report on trail revegetation studies. In: Stanley, J. T., Jr.; Harvey, H. T.; Hartesveldt, R. J., eds. A report on the wilderness impact study: the effects of human recreational activities on wilderness ecosystems with special emphasis on Sierra Club wilderness outings in the Sierra Nevada. San Francisco, CA: Sierra Club, Outing Committee; 1979: 193-196.

Papamichos, N. T. Campground vegetative study, Rocky Mountain National Park, Colorado. 1966. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Rocky Mountain National Park, CO. 101 p.

Parsons, D. J. Wilderness protection: an example from the southern Sierra Nevada, USA. Environmental Conservation. 10: 1-8; 1983.

Parsons, D. J.; DeBenedetti, S. H. Wilderness protection in the High Sierra: effects of a fifteen year closure. In: Linn, R. M., ed. Proceedings, first conference on scientific research in the National Parks. Transactions and Proceedings Series, Number 5. Washington, DC: U.S. Department of the Interior; 1979: 1313-1318.

Parsons, D. J.; MacLeod, S. A. Measuring impacts of wilderness use. Parks. 5(3): 8-12; 1980.

Parsons, D. J.; Stohlgren, T. J.; Fodor, P. A. Establishing backcountry use quotas: an example from Mineral King, California. Environmental Management. 5: 335-340; 1981.

Pfister, Robert D.; Kovalchik, Bernard L.; Arno, Stephen F.; Presby, Richard C. Forest habitat types of Montana. General Technical Report INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 174 p.

Price, M. F. A baseline and planning study of the summer environment of the Sunshine Area, Canadian Rocky Mountains. Calgary, AB: University of Calgary; 1981. 281 p. Thesis.

Price, M. F. A review of research into the impacts of recreation on alpine vegetation in western North America. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological effects of outdoor recreation on mountain areas in Europe and North America. Recreation Ecology Research Group Report No. 9; 1985: 34-52. [Available from Shirley Wright, Department of Horticulture, Wye College, Wye, Ashford, Kent, United Kingdom.]

Proudman, R. D. AMC field guide to trail building and maintenance. Boston, MA: Appalachian Mountain Club; 1977. 193 p.

Pryor, P. J. The effects of disturbance on open *Juncus trifidus* heath in the Cairngorm Mountains, Scotland. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological effects of outdoor recreation on mountain areas in Europe and North America. Recreation Ecology Research Group Report No. 9; 1985: 53-62. [Available from Shirley Wright, Department of Horticulture, Wye College, Wye, Ashford, Kent, United Kingdom.]

Quinn, N. W.; Morgan, R. P. C.; Smith, A. J. Simulation of soil erosion induced by human trampling. Journal of Environmental Management. 10: 155-165; 1980.

Ranz, B. Closing wilderness campsites: visitor use problems and ecological recovery in the Selway-Bitterroot Wilderness, Montana. Missoula, MT: University of Montana; 1979. 125 p. Thesis.

Rechlin, M. A. Recreational impact in the Adirondack high peaks wilderness. Ann Arbor, MI: University of Michigan; 1973. 65 p. Thesis.

Reeves, F. B.; Wagner, D.; Moorman, T.; Kiel, J. The role of endomycorrhizae in revegetation practices in the semi-arid west. I. A comparison of incidence of mycorrhizae in severely disturbed vs. natural environments. American Journal of Botany. 66: 6-13; 1979.

Reid, E. H.; Strickler, G. S.; Hall, W. B. Green fescue grassland: 40 years of secondary succession. Research Paper PNW-274. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 39 p.

Rinehart, R. P.; Hardy, L. C.; Rosenau, H. G. Measuring trail conditions with stereophotography. Journal of Forestry. 76: 501-503; 1978.

Ripley, H. T. Recreation impact on southern Appalachian campgrounds and picnic sites. Research Paper SE-153. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1962. 20 p.

Roach, D. A.; Marchand, P. J. Recovery of alpine disturbances: early growth and survival in populations of the native species, *Arenaria groenlandica, Juncus trifidus*, and *Potentilla tridentata*. Arctic and Alpine Research. 16: 37-43; 1984.

Robinson, T. W. Introduction, spread and areal extent of saltcedar (*Tamarix*) in the western states. Professional Paper 491-A. Washington, DC: U.S. Department of the Interior, Geological Survey; 1965. 12 p.

Roggenbuck, J. W.; Berrier, D. L. Communications to disperse wilderness campers. Journal of Forestry. 79: 295-297; 1981.

Rogova, T. V. Influence of trampling on vegetation of forest meadow and whortleberry-moss-pine forest cenoses. Soviet Journal of Ecology. 7: 356-359; 1976.

Root, J. D.; Knapik, L. J. Trail conditions along a portion of the Great Divide Trail Route, Alberta and British Columbia Rocky Mountains. Report 72-5. Edmonton, AB: Research Council of Alberta; 1972. 24 p.

Rutherford, G. K.; Scott, D. C. The impact of recreational land use on soil chemistry in a provincial park. Park News. 15: 22-25; 1979.

Satchell, J. R.; Marren, P. R. The effects of recreation on the ecology of natural landscapes. Nature and Environment Series, Number 11. Strasbourg, France: Council of Europe; 1976. 117 p.

Saunders, P. R. The vegetational impact of human disturbance on the spruce-fir forests of the southern Appalachian Mountains. Durham, NC: Duke University; 1979. 177 p. Dissertation.

Saunders, P. R.; Howard, G. E.; Stanley-Saunders, B. A. Effect of different boot sole configurations on forest soils. Extension/Research Paper RPA-1980-3. Clemson, SC: Clemson University, Department of Recreation, Park Administration; 1980. 11 p.

Schreiner, E. G. Vegetation dynamics and human trampling in the subalpine communities of Olympic National Park. Seattle, WA: University of Washington; 1974. 150 p. Thesis.

Schreiner, E. Evaluation of the 1976 plant restoration project at Lake Constance after one year. 1977. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Olympic National Park, Port Angeles, WA. 6 p.

Schreiner, E. Long term experimental trampling on plant communities in Denali National Park: progress report. McKinley Park, AK: U.S. Department of the Interior, National Park Service, Denali National Park; 1980. 86 p.

Schreiner, E. G. The role of exotic species in plant succession following human disturbance in an alpine area of Olympic National Park. Seattle, WA: University of Washington; 1982. 132 p. Dissertation.

Schreiner, E. G.; Moorhead, B. B. Human impact studies in Olympic National Park. In: Proceedings, symposium on terrestrial and aquatic ecological studies of the Northwest; 1976 March 26-27; Cheney, WA: Eastern Washington State College; 1976: 59-61.

Schreiner, E. S.; Moorhead, B. B. Human impact inventory and management in the Olympic National Park backcountry. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 203-212.

Scott, R. L. Revegetation studies of a disturbed subalpine community in Olympic National Park, Washington. 1977. Unpublished report on file at: Seattle Pacific University, Seattle, WA. 62 p.

Settergren, C. D.; Cole, D. M. Recreation effects on soil and vegetation in the Missouri Ozarks. Journal of Forestry. 68: 231-233; 1970.

Simon, L. Soil physical properties of selected campsites under varying use levels in the Kearsarge-Bullfrog-Charlotte Lakes area of Kings Canyon National Park. 1978. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Kings Canyon National Park, Three Rivers, CA. 53 p.

Singer, S. W. Vegetation response to single and repeated walking stresses in an alpine ecosystem. New Brunswick, NJ: Rutgers University; 1971. 69 p. Thesis.

Speight, M. C. D. A study of recreational use of the New Forest. London: University College; 1966. Thesis.

Speight, M. C. D. Outdoor recreation and its ecological effects: a bibliography and review. Discussion Papers in Conservation, Number 4. London: University College; 1973. 35 p.

Spiridinov, V. N. Change in species composition of the herbage in herb birch forest under the effect of recreational stress. Soviet Journal of Ecology. 9: 377-379; 1979.

Stankey, G. H. Use rationing in two southern California wildernesses. Journal of Forestry. 77: 347-349; 1979.

Stankey, G. H.; Cole, D. N.; Lucas, R. C.; [and others]. The limits of acceptable change (LAC) system for wilderness planning. General Technical Report INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 37 p.

Stanley, J. T., Jr.; Harvey, H. T.; Hartesveldt, R. J., eds. A report on the wilderness impact study: the effects of human recreational activities on wilderness ecosystems with special emphasis on Sierra Club wilderness outings in the Sierra Nevada. San Francisco, CA: Sierra Club, Outing Committee; 1979. 290 p.

Stelmock, J. J.; Dean, F. C. Vegetation trampling effects analysis—1975 plots, Mount McKinley National Park, Alaska. 1979. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Denali National Park, AK. 67 p.

Stohlgren, T. J. Vegetation and soil recovery of subalpine campsites in Sequoia National Park, California. Fresno, CA: California State University; 1982. 49 p. Thesis.

Strand, S. The impact of pack stock on wilderness meadows in Sequoia-Kings Canyon National Park. In: Stanley, J. T., Jr.; Harvey, H. T.; Hartesveldt, R. J., eds. A report on the wilderness impact study: the effects of human recreational activities on wilderness ecosystems with special emphasis on Sierra Club wilderness outings in the Sierra Nevada. San Francisco, CA: Sierra Club, Outing Committee; 1979: 77-87.

Studlar, S. M. Recovery of trampled bryophyte communities near Mountain Lake, Virginia. Bulletin of the Torrey Botanical Club. 110: 1-11; 1983.

Summer, R. M. Impact of horse traffic on trails in Rocky Mountain National Park. Journal of Soil and Water Conservation. 35: 85-87; 1980.

Sumner, L. A backcountry management evaluation, Sequoia and Kings Canyon National Parks. 1968. Unpublished report on file at: U.S. Department of the Interior, National Park Service, Sequoia-Kings Canyon National Parks, Three Rivers, CA. 62 p.

Sutton, S. W. The impact of floaters on the Ozark National Scenic Riverways. Columbia, MO: University of Missouri; 1976. 152 p. Thesis.

Teschner, D. P.; DeWitt, G. M.; Lindsay, J. J. Hiking impact on boreal forest vegetation and soils in Vermont's northern Green Mountains. Research Note RSM-6. Burlington, VT: University of Vermont, Recreation Management Program; 1979. 13 p.

Thornburgh, D. A. An ecological study of the effect of man's recreational use at two subalpine sites in western Washington. Berkeley, CA: University of California; 1962. 50 p. Thesis.

Vale, T. R. Forest changes in the Warner Mountains, California. Annals of the Association of American Geographers. 67: 28-45; 1977.

Vankat, J. L.; Major, J. Vegetation changes in Sequoia National Park, California. Journal of Biogeography. 5: 377-402; 1978.

Wagar, J. A. The carrying capacity of wildlands for recreation. Forest Science Monograph No. 7. Washington, DC: Society of American Foresters; 1964. 23 p.

Wagar, J. A. Cultural treatment of vegetation on recreation sites. Proceedings, Society of American Foresters. 61: 37-39; 1965.

Walker, R. I. Photography as an aid to wilderness resource inventory and analysis. Fort Collins, CO: Colorado State University; 1968. 114 p. Thesis.

Wall, G.; Wright, C. The environmental impact of outdoor recreation. Department of Geography Publication Series Number 11. Waterloo, ON: University of Waterloo; 1977. 69 p.

Washburne, R. F.; Cole, D. N. Problems and practices in wilderness management: a survey of managers. Research Paper INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 56 p.

Watson, A.; Bayfield, N.; Moyes, S. Research on human pressures on Scottish mountain tundra, soils, and animals. In: Fuller, W. A.; Kevan, P. G., eds. Proceedings, conference on productivity and conservation in northern circumpolar lands. Morges, Switzerland: International Union for Conservation of Nature and Natural Resources; 1970: 256-266.

Weaver, T.; Dale, D. Trampling effects of hikers, motorcycles and horses in meadows and forests. Journal of Applied Ecology. 15: 451-457; 1978.

Weaver, T.; Dale, D.; Hartley, E. The relationship of trail conditions to use, vegetation, user, slope, season, and time. In: Ittner, R.; Potter, D.; Agee, J.; Anschell, S., eds. Proceedings, recreational impact on wildlands; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 94-100.

Whitson, P. D. The impact of human use upon the Chisos Basin and adjacent lands. National Park Service Scientific Monograph Series, Number 4. Washington, DC: U.S. Department of the Interior, National Park Service; 1974. 92 p.

Whittaker, P. L. Comparison of surface impact by hiking and horseback riding in the Great Smoky Mountains National Park. Management Report 24. Atlanta, GA: U.S. Department of the Interior, National Park Service, Southeast Region; 1978. 32 p.

Willard, B. E. Phytosociology of the alpine tundra of Trail Ridge, Rocky Mountain National Park, Colorado. Boulder, CO: University of Colorado; 1963. 243 p.

Willard, B. E.; Marr, J. W. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biological Conservation. 3: 181-190; 1971.

Young, R. A. Camping intensity effects on vegetative ground cover in Illinois campgrounds. Journal of Soil and Water Conservation. 33: 36-39; 1978.

Young, R. A.; Gilmore, A. R. Effects of various camping intensities on soil properties in Illinois campgrounds. Soil Science Society of America Journal. 40: 908-911; 1976.

AUTHOR

David N. Cole
Research Scientist
Systems for Environmental Management
P.O. Box 8868
Missoula, MT 59807

FISH AND WILDLIFE RESEARCH AND WILDERNESS IN THE UNITED STATES: A STATE-OF-KNOWLEDGE REVIEW

Edward E. Starkey
Gary L. Larson

ABSTRACT

A review of wildlife research conducted in the last 15 to 20 years in National Parks and wildernesses is presented to illustrate the close relationship between the two. Wilderness is essential for research on some human-avoiding species. Research is valuable to wilderness through identifying threats and ways to mitigate or avoid impacts of recreation, exotic species, pollution, and development activities. Research information can help predict the consequences of disturbances in these natural ecosystems and provide hope for their preservation.

INTRODUCTION

The National Park and Wilderness Preservation Systems were created to provide for the use and enjoyment of parks and wildernesses while leaving them unimpaired for future generations. However, the underlying motive was "to preserve something precious from a special standpoint which, when analyzed, proved to be based upon some natural phenomenon or other object of interest to scientists or historians" (Albright 1933). Later, the possible presence of "ecological, geological, or other features of scientific, educational, scenic, or historical value" was recognized as an attribute of wilderness (Public Law 88-577, Section 2.c.).

In 1872 when Yellowstone National Park was established, the objectives of providing for recreational use while preserving resources for future generations were not in serious conflict. Visitation was low, and the resource extensive. However, today the situation is far different. Park and wilderness areas are used by millions of visitors each year. Thus, balancing use and preservation of wilderness presents a serious dilemma for resource managers.

Fish and wildlife resources have been especially vulnerable to the pressures of human activities. Many of the species so often considered indicators of wilderness, such as the grizzly bear, wolf, and native cutthroat trout, have been negatively influenced by humans. Parks and wildernesses are also increasingly being influenced by activities outside their boundaries. Perhaps the most serious of these impacts is air pollution, but logging, livestock grazing, poaching, hydroelectric dams, and irrigation developments are other examples. Such impacts are of great concern because they not only impair resources for future recreational enjoyment, but jeopardize the value of wilderness as undisturbed reference areas for ecological research.

Thus, there is a symbiotic relationship between ecological research and wilderness. Research can help detect human-caused changes in wilderness ecosystems, as well as provide knowledge on which to base management programs. Wildernesses, on the other hand, are laboratories within which to study natural processes that are relatively free of human influence, and provide clean or undisturbed reference areas with which the health of managed ecosystems and landscapes can be compared (Franklin 1981).

In our review we have defined wilderness quite loosely, and included studies conducted in many areas that are not legally designated wildernesses. Much of the work described was done in National Parks or other relatively large and undisturbed natural areas. Furthermore, we generally restricted our review to studies conducted during the last 15 to 20 years.

This review is by no means comprehensive. Rather, our primary objective is to present representative examples of both basic and applied fish and wildlife research. Examples of basic research are those studies that have been conducted within parks or wilderness areas because of their uniquely undisturbed condition. Applied studies focus on research designed to monitor or mitigate human impacts on wilderness fish and wildlife.

OVERVIEW OF FISH AND WILDLIFE RESEARCH

We searched computerized data bases maintained by DIALOG Information Services for reference topics, such as fish and wildlife research in National Parks and wilderness. The primary data base searched was BIOSIS PREVIEWS, the online version of Biological Abstracts that contains over 4.5 million citations from more than 9,000 journals and monographs published from 1969 to the present. Additionally we searched AQUATIC SCIENCES AND FISHERIES ABSTRACTS, DISSERTATION ABSTRACTS, ZOOLOGICAL RECORD, CRIS (Current Research Information System)/USDA, and FEDRIP (Federal Research in Progress) data bases.

Search strategies varied among the data bases. For BIOSIS PREVIEWS, a large and relatively general data base, we conducted a hierarchical search that employed progressively more specific keywords. For data bases such as AQUATIC SCIENCES AND FISHERIES ABSTRACTS, this procedure was not necessary; these data bases were limited to a relatively narrow range of topics.

In general we searched these data bases for references that included "wilderness" or "national park" in the title or as a major descriptor. Only those references were obtained for which the relationship to wilderness or National Parks was considered to be important. Although some potentially relevant references may have been missed, a large proportion of the published studies most likely to be of value to wilderness managers were probably found. Furthermore, we believe we obtained a representative sample of published research for our analysis of content.

In all data bases searched, references to National Parks far exceeded those to wilderness. For example, BIOSIS PREVIEWS contained approximately 2,000 references to National Parks compared to about 100 for wilderness. This imbalance probably results from a combination of factors. National Parks are frequently more accessible, have more logistical support, and have a longer research tradition than wilderness areas. Furthermore, "national park" may be more likely used in titles or keywords. Most references dealt with neither fish nor wildlife research. However, many studies provided important background information required to conduct or interpret research concerning fish and wildlife.

BIOSIS PREVIEWS was further searched to include only those references dealing with vertebrate ecology and either wilderness or National Parks. Of the approximately 140 references found, by far the most common taxa studied were mammals. They represented over 60 percent of the studies, with birds, fish, reptiles, and amphibians accounting for the remainder (fig. 1).

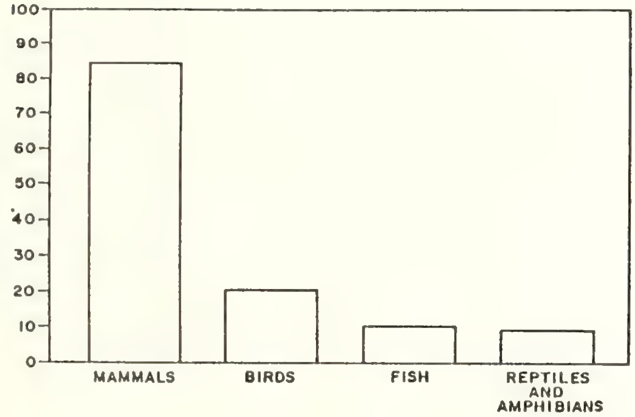


Figure 1.—Vertebrate taxa included in published studies dealing with National Parks or wilderness.

Because mammals were so well represented in the literature, vertebrate references from BIOSIS PREVIEWS were analyzed to determine which mammalian groups had been studied. Cervids (elk, deer, and moose) and small mammals were the most studied, followed by bears, feral pigs, and wolves (fig. 2). A search of the online version of ZOOLOGICAL RECORD, available only for the period 1978 through 1981, yielded similar results except that bears were the most studied group. The prominence of cervids, bears, and small mammals in mammalian research in National Parks and wilderness is probably related to the difficulty in studying more elusive and less abundant animals such as cougars, mountain goats, and wolverines. Additionally, the role of native cervids and bears in park and wilderness ecosystems has historically been controversial and attracted the attention of both the scientific community and the public.

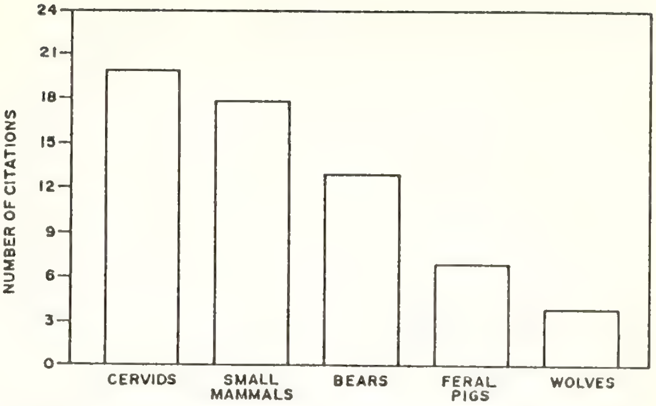


Figure 2.—Mammals included in published studies dealing with National Parks or wilderness.

Thus for parks and wilderness, animal ecology research between the late 1960's and 1984 was heavily oriented toward terrestrial studies. Mammals were the most studied group, bird studies accounted for far fewer references, and studies of fish, reptiles, and amphibians were even less abundant.

BASIC RESEARCH AND WILDERNESS

Many wilderness areas in the United States have been classified as Biosphere Reserves with the primary objectives of conserving the biotic and genetic diversity of plants and animals within natural ecosystems, and providing areas for ecological research, with special emphasis on baseline studies. The following specific research priorities have been identified: (1) monitoring and research to improve understanding of the structure and function of ecosystems and their components; (2) determining environmental consequences of various land management practices; and (3) ensuring the effectiveness of biological reserves in preserving biotic and genetic diversity by consideration of size, habitat heterogeneity, and external influences (Franklin 1977). These objectives and priorities illustrate the importance of wilderness for ecological research, as well as for research on important ecosystem components such as fish and wildlife.

Wilderness and National Park areas have historically provided excellent study areas for wildlife research, and to a lesser extent for fisheries research. The desirability of these areas for research results from the absence of the effects of resource exploitation. Researchers have had the opportunity to study ecosystems that are relatively free from the influence of humans. The undisturbed nature of wilderness is becoming even more important as surrounding areas become progressively more developed and economically exploited.

Wilderness also provides the opportunity to study unthreatened species in an undisturbed environment. Some wildlife studies require extensive tracts of wildland because of behavioral characteristics of certain species, such as large home-range size or sensitivity to disturbance by humans. In the United States, wilderness associated with National Parks has been especially valuable for these studies because hunting is generally not allowed (Franklin 1981). Information obtained from such studies improves the understanding of the fundamental ecology of these species, and may provide insights that are potentially valuable in managing these same species on nonwilderness lands. In many cases, park and wilderness areas serve as experimental controls with which to compare the effects of land management or development activities on adjacent or ecologically similar areas. The following studies illustrate the value of wilderness for basic research.

Ecology of Wolves

Natural regulation of populations is accomplished through a set of controlling mechanisms that limit or control populations in the absence of human influence (Peek 1980). Study of natural regulation must then be conducted in ecosystems in which predators, prey, and habitat are relatively free from human impacts, such as wilderness areas or National Parks.

Wolves and moose have been studied at Isle Royale National Park since 1958 (Mech 1966). During these years important insights into large mammal predator-prey relationships have been gained. For example, Peterson and others (1984) suggested that population fluctuations for moose result from long-term population cycles influenced by both physiological and environmental factors and that wolf population changes lagged behind similar changes in the moose population. The relationship between moose and wolf populations is complex because there are significant time lags in the various feedback mechanisms that tend to result in oscillations and overshooting of equilibria. It is clearly not a simple case of predator and prey reaching a stable equilibrium, with wolves regulating moose in some idealized textbook fashion, although Gasaway and others (1983) concluded that wolf predation can exert substantial control over prey populations under some circumstances.

Wilderness wolf research is of interest to wilderness managers and those interested in preserving the wolf. However, an improved understanding of the population regulation mechanisms influencing moose and other ungulates may also provide valuable information for use in managing hunted populations, as well as assessing the impacts of land management practices.

Ecology of Mountain Lions

Additional insights into predator-prey relationships for large mammals have been provided by studies of mountain lions in the wilderness of central Idaho (Idaho Primitive Area). Hornocker (1970) found that elk and deer populations were limited by food supply and lion predation did not directly determine numbers of elk and deer. However, he suggested that predation by lions dampens and protracts prey oscillations and helps distribute prey more evenly on critical ranges. Furthermore, he concluded that predation was an important evolutionary influence by removing less fit individuals from prey populations, and that this was of great significance in maintaining stability in a wilderness ecosystem.

Subsequently, Seidenstecker and others (1973) determined that the social behavior of mountain lions limited the density of breeding adults within the Idaho Primitive Area to a level below that which could be supported by the available food supply. Although resident lions did not totally exclude others, they occupied fairly distinct home areas. Individual isolation was maintained by avoidance, but the land tenure system was complex; individual relationships changed seasonally and varied between sexes and among age classes.

These basic studies have contributed greatly to an improved understanding of predator-prey relationships. They could only have been conducted in wilderness.

Wolverines and Wilderness

Because wolverines inhabit remote and relatively inaccessible areas, little is known of their population ecology. However, an extensive study of wolverines was conducted in the Bob Marshall Wilderness and adjacent areas of western Montana (Hornocker and Hash 1981). An important conclusion was that wilderness appears to be essential for the continued survival of wolverine populations. Wolverines separated themselves from humans by occupying steep and inaccessible areas during the summer when backcountry use was high, and moving to lowland nonwilderness areas only when snow limited human activity. Wolverines and wilderness users can apparently coexist. Hornocker and Hash concluded that with adequate wilderness habitat, viable wolverine populations should persist in Montana.

Ecology of the Olympic Elk

Throughout the Pacific Northwest, Roosevelt elk (*Cervus elaphus roosevelti*) are hunted, and presently occupy habitat that has been heavily influenced by logging, agriculture, and development. A notable exception is found in Olympic National Park where approximately 10,000 elk occupy undisturbed habitats and are not hunted legally. Excellent opportunities exist to study Roosevelt elk in these relatively pristine habitats.

For approximately the last 10 years, the social behavior, nutrition, and general ecology of these elk have been studied (Jenkins and Starkey 1982, 1984; Leslie and others 1984). This work suggests that elk occupying undisturbed habitats have a more stable and cohesive social structure than those inhabiting managed landscapes. Furthermore, considerable knowledge has been gained of the ecology of elk occupying old-growth forests. Much of this information is useful in assessing the impact of logging on elk populations, and would not be available if Olympic National Park did not exist.

Additionally, this study represents an example of work initiated as basic research, but for which an application arose. In 1983, two members of a neighboring Indian tribe were cited for illegally killing elk within Olympic National Park. Their legal defense involved alleged unextinguished treaty rights. Although the case was eventually won by the Park Service, the research was useful in assessing the potential impacts of tribal hunting on elk in Olympic

National Park. The only recent ecological information on which to base such an assessment had been obtained during the basic research. Clearly, there was not adequate time to initiate new studies.

APPLIED STUDIES AND MONITORING PROGRAMS

Designation or management as wilderness implies that natural resources will be undisturbed and affected only by natural processes. However, management activities and use by visitors often are significant sources of disturbance. Additionally, use and management of adjacent lands as well as anthropogenic changes in atmospheric conditions threaten wilderness ecosystems in many areas. The applied studies and monitoring programs that follow illustrate the role of research in maintaining undisturbed ecosystems in the face of increased competition for natural resources. Many of these examples seem to deal with a single species, such as the desert pupfish or grizzly bear, but actually describe changes in fundamental ecosystem processes. In fact, wilderness is influenced by a variety of internal and external factors. The examples also illustrate the diversity of threats to the integrity of wilderness ecosystems, and the regional and national scope of many of these problems.

Water Development

Because water is such a valuable commodity, particularly in the Western United States, wildernesses and National Parks frequently must compete for this resource with such uses as irrigation, power generation, and human consumption. Nonwilderness needs for water often have the highest priority, and wilderness is thus negatively impacted.

Impoundments.—The Colorado River drainages within Grand Canyon National Park, Canyonlands National Park, and Dinosaur National Monument have undergone extensive changes in hydrology and habitat since hydroelectric dams were built on the main river and its major tributaries (Dolan and others 1974). Research in these areas has documented the nature and magnitude of impacts on riparian and aquatic resources as a consequence of the environmental changes. For example, major alterations include drastic reductions in the frequency of flood peaks, an increase in diurnal discharge levels, decreased water temperatures and silt loads, and marked changes in alluvial morphology and vegetation patterns (Vanicek and Kramer 1969; Dolan and others 1974). These changes were followed by drastic reductions of native fish species, some of which are now endangered, such as the humpback chub (*Gila cypha*) (Holden and Stalnaker 1975). Recent studies suggest that depressed summer water temperatures render the main channel unsuitable for successful reproduction by several species (Kaeding and Zimmerman 1983). But changes in food abundance and type are also important. Reduced growth has been documented for the endangered Colorado squawfish (*Ptychocheilus lucius*) and the Colorado chub (*Gila robusta*) in the Green River downstream from Flaming Gorge Dam (Vanicek and Kramer 1969). The river conditions are so altered in some areas that only native fishes adapted to tributary streams are likely to survive (Holden and Stalnaker 1975). Additional threats include increased numbers and abundance of introduced species (Minckley and Binn 1976). It is difficult to document the impacts to native fishes from these species, but competition for food and space certainly influences native species.

Alteration of Water Levels.—Small populations of native fishes in isolated springs exist within the Death Valley drainage system. Habitat deterioration from removal of riparian vegetation, filling, installation of irrigation equipment in some springs, and general alteration of the water table through irrigation have affected water quality and altered water levels in many springs (Pister 1974). These changes have reduced the abundance of some populations and caused extinction of others (Minckley and Deacon 1968; Pister 1974). One such spring, Devils Hole in a detached portion of Death Valley Monument, is inhabited by the only natural population of the endangered Devils Hole pupfish (*Cyprinodon diabolis*). This situation serves as an example of the sensitivity of isolated populations to environmental changes.

Pumping of ground water from nearby wells decreased the water level in Devils Hole and reduced the amount of water on a rock shelf located near the surface of the spring. The drop coincided with a reduction in the population density of the pupfish. Later studies demonstrated that the shelf was an important feeding and spawning site for the fish (Minckley and Deacon 1973). In response to these findings, the National Park Service and the Nevada Department of Fish and Game suspended a fiberglass shelf beneath the pool surface to provide spawning area for the Devils Hole pupfish. Lights were suspended above the water to enhance algae production in 1970 (Pister 1974). Once the minimum water level was established by court order in 1977, the shelf was removed and lights turned off, but both were left at the site for use in an emergency. In 1972, 27 fish were transferred to an artificial refuge downstream from Hoover Dam. These fish have reproduced but appear to have different body size and other meristic features from the original populations (Pister 1974).

A recovery plan for the Devils Hole pupfish was completed in 1980. The plan describes needs for enforcement; habitat control; monitoring physical, chemical, and biological components of the spring system; maintenance of the Hoover Dam refugium and establishment of another; determination of the factors controlling the population size of the pupfish; public education; and restoration and maintenance of natural conditions. These objectives require a great commitment of time and effort and illustrate the importance of research for preserving even an isolated fish population.

Some large areas like Everglades National Park (6,000 km^2) also have serious native fish problems as a result of alterations of natural hydrologic cycles. The problems at Everglades National Park developed from major alterations of the hydrological systems throughout southeastern Florida by an extensive canal and levee system managed to meet agricultural and urban needs. Research has shown that the system has changed from the original continuous marsh to a series of impoundments designed to release water during flood conditions and impound or divert water during drought. Impacts from these external management actions have major impacts on the park's aquatic habitat, ranging from the dispersal of native fishes and nest failure of wading birds to extensive mortality of fishes during droughts (Loftus 1985). Furthermore, the persistence of abnormally high water over several years in localized areas has caused the fish communities to undergo changes from a marsh to a more lakelike structure (Kushlan 1985). Present research studies are defining the relationships between water conditions and the structure of the freshwater community in the park.

Fluctuating water levels are also a problem in Voyageurs National Park, northern Minnesota. Dams on Rainy Lake and the creation of Namakan Reservoir have greatly altered the hydrologic regime. The Namakan Reservoir is used to buffer the level of Rainy Lake for maximum power generation. This results in greater than natural fluctuations for the Namakan Reservoir, and less than natural fluctuations for Rainy Lake. Also, the pattern of seasonal change has been altered. Fish, wildlife, and littoral plants in the lake have been impacted. A multidisciplinary study has been initiated to assess the relationships between natural and altered fluctuations and develop alternative strategies to minimize human-caused impacts on fish and wildlife populations (Kallemeyn 1983).

Introduced Wildlife Species

Many nonnative and exotic wildlife species have been introduced to wilderness areas of the United States. Some were introduced to provide hunting opportunities; others originated from domestic livestock or escaped pets. Some of these species, such as European wild boar, wild horses, and wild burros, are truly exotic, while others are native to other areas of North America. For example, mountain goats, elk, and wild turkey have all been transported to areas where they are not indigenous. Exotics can greatly influence ecological processes including predator-prey and plant-herbivore relationships, and energy cycles (Goigel and Bratton 1983). The following examples illustrate the use of research to identify the impacts of introduced animals as well as provide a basis for mitigation actions.

Wild Pigs.—True swine (Suidae) are not native to North America (Singer 1981), but arrived with Spanish colonists in the early 16th century. Colonists continued to bring pigs, many of which escaped and served as a source for a feral pig population which spread throughout the Southeastern United States and portions of California by the early 1900's. Presently, wild pigs inhabit 13 areas of the National Park System (Singer 1981).

European wild boar escaped from a hunting preserve in North Carolina in 1913 and are now abundant in Great Smoky Mountains National Park (Goigel and Bratton 1983). The number of wild boar inhabiting Great Smoky Mountains is unknown, primarily because of difficulties involved in censusing the species. However, the population has been estimated at about 1,500 animals found throughout most of the park (Tate 1984).

Wild boar have been responsible for significant changes in the Great Smoky Mountains ecosystem. Hog rooting, feeding, and trampling have greatly influenced forest understory communities (Bratton 1975) and through habitat alteration have the potential for negatively affecting other animal species (Tate 1984).

The basic biology of both European wild boar and feral pigs is now well understood, but information on population estimates, impacts, and management strategies is inadequate. Furthermore, because pig densities, impacts, and response to reduction programs vary greatly among areas, research is required to provide area-specific management information.

Mountain Goats.—Although mountain goats (*Oreamnos americanus*) are native to the Cascade Mountains of Washington, there is no historical evidence of their presence on the Olympic Peninsula prior to their introduction by hunters between 1925 and 1929 (Moorhead and Stevens 1982). At the time of introduction, much of the Olympic Peninsula was managed as a national monument by the U.S. Department of Agriculture, Forest Service, and hunting was allowed. Hunting was subsequently prohibited when the National Park Service assumed management responsibility for the area in 1933. By 1983, goat densities in portions of Olympic National Park were the highest in North America (Stevens 1983), and the total park population exceeded 1,000 (Houston and others 1986).

A program has been established to monitor vegetation impacts of mountain goats in Olympic National Park. However, this has been difficult because no quantitative information exists on vegetation prior to the introduction of goats. Comparison between areas of high and low goat density is not possible because of fundamental ecological differences (Houston and others 1984). These difficulties have been encountered in virtually every area where the impacts of exotic wildlife species have been studied.

Additional research has been conducted on census methods and capture and removal techniques. During 1981-83, 50 to 60 goats were trapped and removed each year from a single area (Klahhane Ridge), and an increased effort was made during the summer of 1985 to remove goats by live capture utilizing helicopters. Future research will focus on the response of mountain goat populations and plant communities, so that effectiveness of management actions can be evaluated.

Introduced Fish

There has been a long history of widespread stocking of native, nonnative, and exotic fish species into lakes and streams in remote areas now designated as wilderness. Concern, first voiced by early fisheries biologists (King 1937), about the potential damage to native gene pools from such plantings continues today. In fact, great care is required when selecting brood stock for supplementation or enhancement of native fish populations. Recent evidence indicates that significant genetic differences can occur between native stocks that could influence reproductive success, even if populations are not separated by great distances (McIntyre 1984).

Introductions of exotic fish species have often coincided with negative changes in native populations. Impacts of exotic fishes include alterations of habitat, introduction of new parasites and diseases, trophic changes, hybridization, and altered spatial relationships (Taylor and others 1984).

Introduced species are most successful in simple communities with low diversity of native species (Minckley and Deacon 1968), in disturbed sites (Taylor and others 1984), or in lakes naturally barren of fish.

Interactions between introduced species and native species may be minimal but these situations still compromise the native; habitat partitioning often results (Nilsson 1967). In other cases the interactions may be great enough to cause or contribute to the extinction of a native species, especially those with limited indigenous ranges such as desert spring fishes, or drastically reduce their distributions, enhancing isolation (Minckley and Deacon 1968). Research results do not support contemporary views favoring the introduction of nonnative and exotic fishes into wilderness areas. Long-term impacts on native fishes are a primary concern.

Native and Introduced Cutthroat Trout.—A genetic reconnaisance of native westslope cutthroat trout (*Salmo lewisi clarki*) was recently completed in lakes of Glacier National Park (Marnell 1981). The purpose of the study was to document the genetic composition of native populations after millions of nonnative Yellowstone cutthroat trout (*Salmo clarki bouvieri*) had been planted from 1912 to the late 1960's. Marnell discovered that pure populations of *lewisi* still exist. He also discovered, however, that some lakes contained westslope-Yellowstone hybrids and others (naturally barren lakes) only *bouvieri*. Despite extensive stocking programs, Marnell concluded that selection pressures appear to favor the native over *bouvieri* in most cases. Nonetheless, part of the gene pool of the native subspecies has been lost through hybridization.

Varley (1979) described the status and ecology of the Yellowstone cutthroat trout and the Snake River finespotted cutthroat trout (*S. clarki* subsp.). The two subspecies still occupy significant portions of their native ranges and possess great genetic and behavioral variability as illustrated by their wide range of spawning seasons, spawning sites, fry emergence behavior, feeding behaviors, and specific habitats. These adaptations represent different ecotypes. Varley argued that management of these ecotypes will maintain the genetic variability of the indigenous gene pool and supported a registry of the ecotype varieties.

These studies are good examples of how research can be used to identify the existence of native gene stocks. Such information offers managers a better understanding of the diversity and status of natural resources that can make important contributions to management's strategies, policies, and actions.

Native Brook Trout and Introduced Rainbow Trout.—From early in this century until about 1937, about 60 percent of the area now in Great Smoky Mountains National Park was logged (White 1980). Logging and related activities greatly deteriorated stream water quality. These conditions plus heavy fishing pressures resulted in drastic declines in the abundance of native brook trout, especially at the lower elevations where the disturbances were most intense. Nonnative rainbow trout were stocked in the disturbed reaches and to a limited extent at higher elevations from logging railroad trestles. Stocking continued at the lower elevations of many park streams into the 1960's by the National Park Service. Studies by King (1937), Lennon (1967), and Kelly and others (1980) showed that the rainbow trout have done very well and, in fact, have extended their distribution by immigrating upstream into remnant brook trout populations in unlogged portions of the watersheds. This expansion coincided with further reductions in the range of brook trout. In fact, most brook trout populations now occupy short sections of small tributary mountain streams high in elevation and gradient (Larson and Moore 1985).

Continued encroachment by nonnative rainbow trout stimulated two research studies. The first was an assessment of the population structure of each species at different stages of encroachment. The results supported the hypothesis that interaction with rainbow trout is a major reason for the continued decline of the natives (Larson and Moore 1985). The second was an experimental study to assess the feasibility of eradicating sympatric rainbow trout from four remnant brook trout populations in 1976. Although chemical treatments had been used years earlier in the park to eradicate rainbow trout (Lennon and Parker 1959), backpack electrofishing was the only technique allowed at the time of this work. Rainbow trout populations were greatly reduced, but not eradicated, after up to 6 years of electrofishing (Moore and others 1983). Recovery rates of the brook trout populations differed between streams, but reached maximum densities by the end of the study (Moore and others 1986). Additional work will be required to determine the long-term effects of electrofishing on the rainbow trout-brook trout relationships. Nonetheless, this research demonstrated that the electrofishing technique was useful for population control, but not eradication. It also showed that brook trout increased in density after removal of the rainbow trout, providing additional support for the hypothesis that rainbow trout have a negative impact on brook trout.

Wild and Hatchery Salmon Stocks.—Management of wild fish stocks on Washington's Olympic Peninsula is controversial and complex, largely a result of conflicting interests of various management agencies and user groups. However, a number of studies have been conducted (Walton and Houston 1984), and research will undoubtedly play an important role in future management planning.

Substantial populations of anadromous fish utilize Olympic National Park during portions of each year. Most of these populations are heavily harvested outside park boundaries by commercial and sport fishing on the lower reaches of the rivers, or at sea. Recreational fishing is also allowed within the park (Houston and Contor 1984).

Large numbers of hatchery fish are introduced to several of the rivers annually, and a major proportion of the harvest consists of these introduced fish. The hatchery stocks have been derived from both native local stocks and those transferred from other areas. There is a potential for alteration of the genetic makeup of existing wild stocks, but it is unclear how effective hatchery stocks are in spawning in the wild. Wild stocks may also be negatively influenced by competition with hatchery juveniles for resources, but more commonly wild stocks are impacted as a result of the high harvest rates imposed on hatchery stocks (Houston 1983). Hatchery coho stocks may be harvested at rates up to 95 percent, compared to the 60- to 75-percent harvest that can usually be sustained by wild stocks (Wright 1981).

Changes in Atmospheric Quality

Although wilderness areas are usually remote from industrial and urban areas of the Eastern United States, wilderness fish and wildlife are nonetheless exposed to air pollution and acid rain, because many pollutants travel long distances (Cowling and Linthurst 1981). Also, wilderness areas of the Western United States may be influenced by acid rain resulting from automobile emissions in urban areas (Glass and others 1981).

Impacts of Acidic Atmospheric Deposition.—Acidic atmospheric deposition has tremendous potential for impacts on aquatic ecosystems in general, and especially areas where lakes and streams are low in alkalinity (Glass and others 1981). Acidification of atmospheric deposition results from pollutants (especially oxides of nitrogen and sulfur) from industry, metal smelting, and combustion of fossil fuels (Haines 1981). Regions in North America with low capacities to neutralize these acidic inputs have shown decreases in stream and lake pH and increased concentrations of metals, especially aluminum (Haines 1981). Impacts to aquatic systems from these changes in water quality can extend to all trophic levels; but the impacts are variable, depending on the species involved, pH, concentration, and type of metal (Schindler and others 1985). In some cases the conditions can be acutely toxic to fishes (Schofield 1976). Less severe conditions can lead to death of a population through loss or reduction of reproduction, to reduced growth (Beamish 1974), and to skeletal deformities (Beamish 1972). Because large areas of the United States are considered moderately to highly sensitive to acidic atmospheric deposition, and because about two-thirds of the land area is receiving such inputs (Cowling 1982), the potential for impacting fish populations in wilderness areas is quite high.

Lakes in the Adirondack State Park of New York, the Boundary Waters Canoe Area-Voyageurs National Park of Minnesota, and Nicolet National Forest of northern Wisconsin are especially sensitive to the effects of acid precipitation (Glass and others 1980). In the Adirondack area, pH values have declined to such a low level that approximately 100 lakes are fishless (Schofield 1976). In northern Minnesota and Wisconsin lake acidification is just beginning, but the annual average pH of precipitation in the region is approximately 4.6 and the potential for ecological damage is great (Glass and others 1980).

Impacts of acid rain are not restricted to fish, but relatively little research has been conducted to document the response of other wildlife species. Bird species such as loons, ospreys, and blue herons, that depend on aquatic organisms for food, may be especially vulnerable (Loucks 1980).

Many western lakes, streams, and soils are potentially sensitive to acidification. Acid rain is common in the Cascade Mountains of Washington and the Sierra Nevada Mountains of California (Powers and Rambo 1981). For example, the North Cascade Mountains of Washington receive precipitation with pH values as low as 4.0 (Powers and Rambo 1981). The potential for ecological damage from acid rain is not restricted to the eastern portion of the United States. Many large western wilderness areas are likely to be impacted in the future.

Air Pollution.—In addition to pollutants that cause acidification of precipitation, trace elements, metals, nonmetallic ions, organic compounds, radioactive particulates, and photochemical oxidants such as ozone can have both lethal and sublethal effects on fish and wildlife (Newman and Schreiber 1984).

Unfortunately, there have been few studies of the effects of such pollutants on fish and wildlife of wilderness areas. However, anthropogenic inputs of polychlorinated biphenyls and trace elements have been described for remote lakes of Rocky Mountain National Park (Heit and others 1984) and elevated lead levels have been reported for forest litter in Great Smoky Mountains National Park (Wiersma and Brown 1980). Concentrations of heavy metals and sulfur in subalpine fir and lichen are higher in Mount Rainier National Park than in these species in Olympic National Park; this suggests that prevailing westerly winds transport pollutants to Mount Rainier from the Seattle-Tacoma metropolitan areas (Frenzel and others 1985). Research is currently under way to determine whether wildlife in these two parks also have differing tissue concentrations of these elements.

Impacts of Recreational Use

With increasing use of wilderness areas, the potential for conflicts between humans and wildlife has also increased. Wildlife is exposed to a variety of disturbances, ranging from harassment to the mere presence of humans. In general, humans were not an important selective factor in the evolution of most wilderness wildlife species. Thus, even low-level exposure to humans may cause significant changes in their behavior and distribution.

Recreational impacts on fish and wildlife are part of the dilemma of providing for use and enjoyment while preserving wilderness resources for future generations. However, human impacts on wilderness wildlife are often subtle and difficult to measure. Animals may avoid humans by changing their spatial distribution or restricting activity to periods of low human disturbance such as evenings or early mornings. Alternatively, they may become habituated to the presence of humans and even learn to obtain food from them. In either case, the naturalness of the wilderness ecosystem is compromised.

Grizzly bears and common loons are generally considered to be wilderness species, and both inhabit areas that receive intense recreational use. The following discussion of these two species illustrates the difficulties in determining impacts of wilderness users on wildlife in general, as well as the need for research to develop mitigating measures.

Grizzly Bears and People.—Conflicts between bears and backcountry users are especially serious because of the likelihood of personal injury or property damage. Because of concern for public safety, injuries and fatalities from grizzly bear attacks frequently trigger proposals to eliminate bears from areas such as National Parks (Moment 1969, 1970). Clearly such actions would be contradictory to the fundamental purposes for protecting wilderness.

Management of wilderness areas inhabited by grizzly bears has thus commonly focused on strategies to allow coexistence with humans (Jope and Shelby 1984). In most areas, these strategies have been successful. In Glacier National Park from 1910 to 1982, there were 24 grizzly bear-visitor confrontations resulting in 27 injuries and six deaths. Most of these confrontations occurred between 1951 and 1982, and the number of confrontations was highly correlated with park visitation. During this time, total visitation ranged from nearly 7 million for the decade of the 1950's to over 12 million in the 1970's (Martinka 1982). Apparently the probability of individual visitors being confronted by grizzly bears did not change significantly during this period.

There is growing concern about possible changes in grizzly bear behavior resulting from exposure to humans. Research suggests that grizzly bears' wariness of people has recently declined in some areas through habituation (Jope 1985). The influence of habituation on incident and injury probabilities is uncertain. Loss of fear of humans could increase risk of hiker injuries (Martinka 1982; McCullough 1982) or in some circumstances reduce the likelihood of charges by grizzly bears (Jope and Shelby 1984), especially if backcountry users behave in a predictable fashion by remaining on trails, not traveling at night, and wearing "bear bells" (Jope 1985).

Further research is needed to provide managers with information required to ensure grizzly bears and humans can coexist in wilderness areas. Perhaps the easiest solution is to close areas of high grizzly density to backcountry users, or to use computer models to identify travel patterns that would minimize the risk of encounters with grizzly bears (Stuart 1978).

However, some wilderness users believe that exposure to danger is part of a wilderness experience. There is an important philosophical question involved in restricting visitor use for safety purposes, but encounters with grizzly bears clearly represent more than a hazard to backcountry users.

From 1973 through 1983, 31 known mortalities of adult female grizzly bears occurred in Yellowstone National Park and the adjacent area (Knight and Eberhardt 1984). About one-third were killed by government agents or individuals in self-defense or to protect against property damage. Significant numbers of deaths are not reported (Blanchard and Knight 1980). Because the reproductive rate of grizzly bears in the area is low and declining, the population is sensitive to loss of reproductive-age females. The difference between continued decline and population stability in the Yellowstone area may be as few as one or two bear mortalities a year (Knight and Eberhardt 1984). Therefore, human-caused mortalities must be kept to a minimum and careful monitoring of grizzly bear populations will be critical.

Common Loons and Recreational Use of Wilderness.—Common loons are summer residents of lakes in the boreal forest areas of northern North America. Recreational use of these lakes has increased greatly during recent years. For example, from 1950 to 1976, visitation to the Boundary Waters Canoe Area of the Superior National Forest increased eightfold (Titus and VanDruff 1981). Increased recreational use may be responsible for many nest failures of common loons in this area (Ream 1976).

Titus and VanDruff (1981) concluded that there was little or no effect of heavy recreational use on loon productivity, and suggest that loons may be habituating to the presence of humans. From 1951 to 1976 when recreational use increased greatly, loon populations increased by about 35 percent. However, some negative effects of human use were documented. Loons on lakes where motors were allowed were less successful in hatching eggs than those on lakes where motors were prohibited. Also, loon pairs nesting near areas of intense human use produced fewer surviving young than those exposed to fewer human contacts.

As for grizzly bears, additional research is required to more fully understand the response of common loons to increased wilderness use. Further research on habituation is extremely important because it may be possible to reduce behavioral impacts by gradually increasing recreational use to allow loons an opportunity to habituate to humans. However, the desirability of habituation of wilderness wildlife to humans is uncertain.

Impacts of Fishing.—Although hunting is generally not permitted in National Parks, fishing has historically been a popular activity in many parks, and is commonly allowed in wilderness areas. As a result of increasing angling pressure, management of fish populations has become an important activity in many park and wilderness areas.

Yellowstone National Park is famous for its fishery resources (Varley and Schullery 1983) and provides a good example of the challenges faced by managers in providing a quality recreational experience and maintaining natural fish populations. Fishing pressure has been heavy throughout the history of the park. A variety of management techniques have been applied, ranging from no size or creel limits to a "catch and release" policy (Varley 1984). The response of the lake and stream fish populations has been variable, reflecting the complex relationships among the environmental conditions, the ecology of fish species, and fishing pressure. The two studies that follow were designed to monitor the effects of changes in fishing regulations.

Very soon after the establishment of Yellowstone National Park, heavy fishing pressure began to negatively influence the native cutthroat trout in Yellowstone Lake. Between the 1880's and late 1960's several regulations were imposed on the fishery to protect the resource (Gresswell 1980). In the 1970's, a 356-mm (14-inch) minimum size limit was instituted, and although there was an initial improvement in the fish population, an increase of effort and harvest decreased the abundance of the larger classes in the fish population. A major change in the regulations was made in 1975 when a 330-mm (13-inch) maximum size was imposed. Larger fish have become more abundant, even though angling success has increased (Gresswell 1983). Long-term studies are required, however, to evaluate the results of these changes in regulations (Gresswell 1980).

Yellowstone River has been a popular fishing area also. Numerous regulations were applied in attempts to protect the native cutthroat trout in the river, but these were not successful (Varley 1984). In 1973 a "catch and release" regulation was adopted. This resulted in an initial drop in angler use, probably caused by factors such as dispersal of anglers and decreased park visitation. However, use increased in subsequent years and by 1981 it exceeded that prior to the "catch and release" regulation. The average age and length of fish have increased and angler satisfaction seems to be high (Varley 1984).

Genetics and Wilderness Management

The survival of any species depends on its having enough genetic diversity to respond to new selection pressures resulting from changes in its environment. An important variable that influences genetic diversity is the area of habitat available to given species. Larger areas typically have greater habitat heterogeneity and support greater populations with greater genetic diversity than smaller areas (Schonewald-Cox 1983).

There has been considerable concern over the adequacy of existing parks and wildernesses to support existing species over the long term. Since the 1970's a number of research studies have been published that deal with the biogeographic similarities of protected reserves and islands, and examine species-area relationships for large mammals. Much of the work has been done outside the United States, but may be applicable. Apparently, most existing reserves are too small to maintain certain animal species indefinitely (Schonewald-Cox 1983). This may be especially true for large herbivores and carnivores; some forms of genetic management may be necessary to preserve some of these species. Schonewald-Cox (1983) has developed initial guidelines for management of genetic diversity in parks or reserves but further research will be required as a basis for wilderness planning and management.

FUTURE RESEARCH NEEDS

Most ecological research in wilderness and National Parks has been terrestrial in orientation. This may be related to management needs or reflect a historic preoccupation with the study of mammals, and to a lesser extent birds. This emphasis is likely to continue because of the value of reserves in the preservation of large mammal species such as wolves and bears.

While terrestrial studies will continue to be important in managing and preserving wilderness, there are many potential threats to aquatic wilderness ecosystems such as fishing, exotic species, and acid rain. Increased emphasis must be placed on aquatic research in parks and wilderness so that changes in aquatic ecosystems can be detected and interpreted in a timely fashion. It should also be recognized that aquatic systems are only parts of watersheds and must be considered in the broader context (Warren 1979; Vannote and others 1980). Greater understanding of the relationships between aquatic systems and watershed processes is needed (Lotspeich and Platts 1981; Everest and Sedell 1983).

Fish and wildlife research will play an even more important role in wilderness management for the foreseeable future. Both increasing visitor use and growing external threats will challenge our ability to maintain the integrity of these relatively undisturbed ecosystems, and management decisions must be based on an increasingly sophisticated understanding of wilderness ecology.

Managers have already become more dependent on ecological information. For example, decisions to control exotic animals such as feral pigs or introduced mountain goats can no longer simply be based on arbitrary agency policy. The public demands scientific support for such management decisions; ecological damage must be demonstrated. This trend is likely to continue in the future.

Cooperation between social and biological scientists will be especially important in developing wilderness use plans that optimize fish, wildlife, and recreational values. Visitor use will continue to be potentially threatening to wilderness wildlife. However, we believe that recreational impacts on wilderness can be more easily mitigated than impacts from extramural sources. Although demand of wilderness recreation is likely to remain high, this can be readily managed by such means as restricting access, establishing limits on backcountry use, or even by closing areas. However, decisions to constrain the public use of these areas must be based on sound information, which in many cases can only be obtained through research.

Unfortunately, thorough research cannot be hurried. Wilderness research needs must be identified well in advance of anticipated problems, or managers must be willing to implement interim management policies until more information is obtained. Thus both basic and applied fish and wildlife research must be encouraged.

The understanding of ecological processes that can be obtained from basic research is especially important in assessing and documenting human-caused changes in wilderness. Unless we first understand the natural processes and dynamics of wilderness ecosystems, it is impossible to determine cause and effect relationships.

Ecological research must be more systems oriented. Study of single species or narrowly defined natural communities will continue to be important (Hornocker 1978), but a broader perspective will be required to understand and preserve wilderness ecosystems.

In many areas, synthesis and analysis of existing information will be of more value than the initiation of new field studies (Wright and Hayward 1985). Models will play an increasingly important role in the identification of information gaps, as well as prediction of the consequences of both natural and human-caused disturbance of wilderness ecosystems (Houston 1982).

We believe that only through research can we hope to preserve parks and wilderness from the many threats presently impinging on them. Difficult social and political choices lie ahead, and these decisions must be based on high-quality information obtained through research.

ACKNOWLEDGMENTS

We wish to express our appreciation to the numerous fish and wildlife professionals who so helpfully provided reprints and unpublished reports. We also thank Deborah Allen, Richard Frenzel, and Kurt Jenkins for critically reviewing the manuscript.

REFERENCES

Albright, H. M. Research in the national parks. The Scientific Monthly. 1933 June: 483-501.

Baker, J. K. The feral pig in Hawaii Volcanoes National Park. In: Linn, R. M., ed. Proceedings of the first conference on scientific research in national parks; 1976 November 9-12; New Orleans, LA. Transactions and Proceedings Series Number 5. Washington, DC: U.S. Department of the Interior, National Park Service; 1979: 365-367.

Beamish, R. J. Lethal pH for the white sucker *Catostomus commersoni* (Lacepede). Transactions of the American Fisheries Society. 101(2): 355-358; 1972.

Beamish, R. J. Loss of fish populations from unexploited remote lakes in Ontario, Canada as a consequence of atmospheric fallout of acid. Water Research. 8(1): 85-95; 1974.

Blanchard, B. M.; Knight, R. R. Status of grizzly bears in the Yellowstone system. In: Sabol, Kenneth, ed. Transactions of the forty-fifth North American wildlife and natural resources conference; 1980 March 22-26; Miami, FL. Washington, DC: Wildlife Management Institute; 1980: 263-267.

Bratton, S. P. The effect of the European wild boar, *Sus scrofa*, on gray beech forest in the Great Smoky Mountains. Ecology. 56(6): 1356-1366; 1975.

Cowling, E. B. Acid precipitation in historical perspective. Environmental Science and Technology. 16(2): 110A-123A; 1982.

Cowling, E. B.; Linthurst, R. A. The acid precipitation phenomena and its ecological consequences. BioScience. 31: 649-654; 1981.

Dolan, R.; Howard, A.; Gallenson, A. Man's impact on the Colorado River in the Grand Canyon. American Scientist. 62(4): 392-401; 1974.

Everest, F. H.; Sedell, J. R. Natural propagation and habitat improvement. Volume 1 - Oregon. Supplement A: evaluation of fisheries enhancement projects on Fish Creek and Wash Creek. Final Report 1983. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, and Oregon State University; 1983. 99 p.

Frankel, O. H. The place of management in conservation. In: Schonewald-Cox, C. M.; Chambers, S. M.; MacBryde, B.; Thomas, W. L., eds. Genetics and conservation: a reference for managing wild animal and plant populations. Menlo Park, CA: Benjamin/Cummings; 1983: 1-14.

Franklin, J. F. The Biosphere Reserve Program in the United States. Science. 195(4275): 262-267; 1977.

Franklin, J. F. Wilderness ecosystems. In: Hendee, J. C.; Stankey, G. H.; Lucas, R. C., eds. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 191-212.

Franklin, J. F. Wilderness for baseline ecosystem studies. In: Proceedings, 17th IUFRO World Congress; Ibaraki, Japan: Japanese IUFRO Congress Committee; 1981: 37-48.

Frenzel, R. W.; Witmer, G. W.; Starkey, E. E. Concentrations of metals and sulfur in subalpine fir needles and a lichen in Olympic and Mount Rainier National Parks, Washington. Corvallis, OR: Oregon State University, College of Forestry, Cooperative Park Studies Unit; 1985. 32 p.

Fritts, S. H.; Mech, L. D. Dynamics, movements, and feeding ecology of a newly protected wolf population in northwestern Minnesota. Wildlife Monograph 80. Washington, DC: Wildlife Management Institute; 1981. 79 p.

Gasaway, W. C.; Stephenson, R. O.; Davis, J. L.; Shepherd, P. E. K.; Burris, O. E. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monograph 84. Washington, DC: Wildlife Management Institute; 1983. 50 p.

Glass, G. E.; Bridges, T. G.; Loucks, O. L. Impact assessment of airborne acidic deposition on the aquatic environment of the United States and Canada. EPA-600/10-81-000. Washington, DC: U.S. Environmental Protection Agency; 1981. 152 p.

Glass, N. R.; Glass, G. E.; Rennie, P. J. Effects of acid precipitation in North America. Environment International. 4(5-6): 443-452; 1980.

Goigel, M.; Bratton, S. Exotics in the parks. National Parks. 57(1-2): 25-29; 1983.

Gresswell, R. E. Special regulations: the Yellowstone Park experience. In: Proceedings of the Western Association of Fish and Wildlife Agencies and the Western Division American Fisheries Society; 1983 July 10-14; Teton Village, WY. [Publisher and place of publication unknown]; 1983: 89-95.

Gresswell, R. R. The effects of the 330 mm maximum size limit on the cutthroat trout fishery of Yellowstone Lake. In: Whaley, R., ed. Proceedings of the 15th annual meeting of the Colorado-Wyoming chapter of the American Fisheries Society. [Location, publisher, and place of publication unknown]; 1980: 70-76.

Haines, T. A. Acidic precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society. 110(6): 669-707; 1981.

Heit, M. C.; Klusek, C.; Baron, J. Evidence of deposition of anthropogenic pollutants in remote Rocky Mountain lakes. Water, Air, and Soil Pollution. 22: 403-416; 1984.

Holden, P. B.; Stalnaker, C. B. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. Transactions of the American Fisheries Society. 104(2): 217-231; 1975.

Hornocker, M. G. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildlife Monograph 21. Washington, DC: Wildlife Management Institute; 1970. 39 p.

Hornocker, M. G. Interactions between threatened and endangered species and wilderness. In: Transactions of the forty-third North American wildlife and natural resources conference; [date and location of conference unknown]. Washington, DC: Wildlife Management Institute; 1978: 344-350.

Hornocker, M. G.; Hash, H. S. Ecology of the wolverine in northwestern Montana. Canadian Journal of Zoology. 59(7): 1286-1301; 1981.

Houston, D. B. The northern Yellowstone elk: ecology and management. London, New York: Macmillan; 1982. 474 p.

Houston, D. B. Anadromous fish in Olympic National Park: a status report. Port Angeles, WA: U.S. Department of the Interior, National Park Service, Olympic National Park; 1983. 37 p.

Houston, D. B.; Contor, R. J. Anadromous fish in Olympic National Park: status and management considerations. In: Walton, J. M.; Houston, D. B., eds. Olympic wild fish conference: proceedings of a conference; 1983 March 23-25; Port Angeles, WA. [Publisher and place of publication unknown]; 1984: 97-111.

Houston, D. B.; Moorhead, B. B.; Olson, R. W. An aerial census of mountain goats in the Olympic Mountain Range, Washington. Northwest Science. 60(2): 131-136; 1986.

Houston, D. B.; Moorhead, B.; Schreiner, E.; Olson, R. Mountain goat ecology and management investigations, Olympic National Park, 1983. Port Angeles, WA: U.S. Department of the Interior, National Park Service, Olympic National Park; 1984. 142 p.

Jenkins, K. J.; Starkey, E. E. Social organization of Roosevelt elk in an old-growth forest. Journal of Wildlife Management. 46: 331-334; 1982.

Jenkins, K. J.; Starkey, E. E. Habitat use by Roosevelt elk in unmanaged forests of the Hoh Valley, Washington. Journal of Wildlife Management. 48(2): 642-646; 1984.

Jope, K. L. Implications of grizzly bear habituation to hikers. Wildlife Society Bulletin. 13(1): 32-37; 1985.

Jope, K. L.; Shelby, B. Hiker behavior and the outcome of interactions with grizzly bears. Leisure Sciences. 6(3): 257-270; 1984.

Kaeding, L. R.; Zimmerman, M. A. Life history and ecology of the humpback chub in the Little Colorado and Colorado Rivers of the Grand Canyon. Transactions of the American Fisheries Society. 112(5): 577-594; 1983.

Kallemeyn, L. W. Action plan for aquatic research at Voyageurs National Park. Park Science. 4(1): 18; 1983.

Kelly, G. A.; Griffith, J. S.; Jones, R. D. Changes in distribution of trout in Great Smoky Mountains National Park, 1900-1977. Technical Report 102. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1980. 10 p.

King, W. Notes on the distribution of native speckled and rainbow trout in the streams of Great Smoky Mountains National Park. Journal of the Tennessee Academy of Science. 12: 351-361; 1937.

Knight, R. R.; Eberhardt, L. L. Projected future abundance of the Yellowstone grizzly bear. Journal of Wildlife Management. 48(4): 1434-1438; 1984.

Kushlan, James. Personal communication. Everglades National Park; 1985.

Larson, G. L.; Moore, S. E. Encroachment of exotic rainbow trout into stream populations of native brook trout in the southern Appalachian Mountains. Transactions of the American Fisheries Society. 114(2): 195-203; 1985.

Lennon, R. E. Brook trout of Great Smoky Mountains National Park. Technical Paper 15. Washington, DC: U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife; 1967. 18 p.

Lennon, R. E.; Parker, P. S. The reclamation of Indian and Abrams Creeks, Great Smoky Mountains National Park. Special Scientific Report, Fisheries 306. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1959. 22 p.

Leslie, D. M., Jr.; Starkey, E. E.; Vavra, M. Elk and deer diets in old-growth forests in western Washington. Journal of Wildlife Management. 48(3): 762-775; 1984.

Loftus, William. Personal communication. Everglades National Park; 1985.

Lotspeich, F. B.; Platts, W. S. An integrated land-aquatic classification. In: Armantrout, N. B., ed. Acquisition and habitat utilization of aquatic inventory information: Proceedings of a symposium; 1981 October 28-30; Portland, OR. Bethesda, MD: Western Division of the American Fisheries Society; 1981: 103-108.

Loucks, O. L. Acid rain: living resource implications and management needs. In: Sabol, Kenneth, ed. Transactions of the forty-fifth North American wildlife and natural resources conference; 1980 March 22-26; Miami Beach, FL. Washington, DC: Wildlife Management Institute; 1980: 24-37.

Marnell, L. F. Genetic reconnaisance of cutthroat trout, *Salmo clarki* Richardson, in twenty-two westslope lakes in Glacier National Park, Montana. Research Report. West Glacier, MT: U.S. Department of the Interior, National Park Service, Glacier National Park; 1981. 47 p.

Martinka, C. J. Rationale and options for management in grizzly bear sanctuaries. In: Sabol, Kenneth, ed. Transactions of the forty-seventh North American wildlife and natural resources conference; 1982 March 26-31; Portland, OR. Washington, DC: Wildlife Management Institute; 1982: 470-475.

McCullough, D. R. Behavior, bears, and humans. Wildlife Society Bulletin. 10: 27-33; 1982.

McIntyre, J. D. Differentiation of anadromous salmonid stocks. In: Walton, J. M.; Houston, D. B., eds. Olympic wild fish conference: Proceedings of a conference; 1983 March 23-25; Port Angeles, WA. [Publisher and place of publication unknown]; 1984: 9-15.

Mech, L. D. The wolves of Isle Royale. Fauna Series 7. Washington, DC: U.S. Department of the Interior, National Park Service; 1966. 210 p.

Minckley, C. O.; Binn, D. W. Summer distribution and reproductive status of fish of the Colorado River in Grand Canyon National Park and vicinity. Technical Report 14. Grand Canyon, AZ: U.S. Department of the Interior, National Park Service, Grand Canyon National Park; 1976. 17 p.

Minckley, C. O.; Deacon, J. E. Southwestern fishes and the enigma of "endangered species." Science. 159(3822): 1424-1432; 1968.

Minckley, W. L.; Deacon, J. E. Observations on the reproductive cycle of *Cyprinodon diabolis*. Copeia. 1973(3): 610-613.

Moment, G. B. Bears and conservation: realities and recommendations. BioScience. 19(11): 1019-1020; 1969.

Moment, G. B. Man-grizzly problems - past and present: implications for an endangered species. BioScience. 20: 1142-1144; 1970.

Moore, S. E.; Larson, G. L.; Ridley, B. Population control of exotic rainbow trout in streams of a natural area park. Environmental Management. 10(2): 215-219; 1986.

Moore, S. E.; Ridley, B.; Larson, G. L. Standing crops of brook trout concurrent with removal of rainbow trout from selected streams in Great Smoky Mountains National Park. North American Journal of Fisheries Management. 3(1): 72-80; 1983.

Moorhead, B. B.; Stevens, V. Introduction and dispersal of mountain goats in Olympic National Park. In: Starkey, E. E.; Franklin, J. F.; Matthews, J. W., eds. Ecological research in national parks of the Pacific Northwest. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1982: 46-50.

Newman, J. R.; Schreiber, R. K. Animals as indicators of ecosystem responses to air emissions. Environmental Management. 8(4): 309-324; 1984.

Nilsson, N. A. Interactive segregation between fish species. In: Gerking, S. D., ed. The biological basis of freshwater fish production. Oxford, England: Blackwell Scientific Publications; 1967: 295-313.

Peek, J. M. Natural regulation of ungulates (what constitutes a real wilderness?). Wildlife Society Bulletin. 8(3): 217-227; 1980.

Peterson, R. O.; Page, R. E.; Dodge, K. M. Wolves, moose, and the allometry of population cycles. Science. 224(4655): 1350-1352; 1984.

Pister, E. P. Desert fishes and their habitats. Transactions of the American Fisheries Society. 103(3): 531-540; 1974.

Powers, C. F.; Rambo, D. L. The occurrence of acid precipitation on the West Coast of the United States. Environmental Monitoring and Assessment. 1: 93-105; 1981.

Ream, C. H. Loon productivity, human disturbance, and pesticide residues in northern Minnesota. Wilson Bulletin. 88(3): 427-432; 1976.

Schindler, D. W.; Mills, K. H.; Malley, D. F.; [and others]. Long-term ecosystem stress: the effects of years of experimental acidification on a small lake. Science. 228: 1395-1401; 1985.

Schofield, C. S. Acid precipitation: effects on fish. Ambio. 5: 228-230; 1976.

Schonewald-Cox, C. M. Conclusions: guidelines to management. In: Schonewald-Cox, C. M.; Chambers, S. M.; MacBryde, B.; Thomas, W. L., eds. Genetics and conservation: a reference for managing wild animal and plant populations. Menlo Park, CA: Benjamin/Cummings; 1983: 414-445.

Seidenstocker, J. C., IV; Hornocker, M. G.; Wiles, W. V.; Messick, J. P. Mountain lion social organization in the Idaho Primitive Area. Wildlife Monograph 35. Washington, DC: Wildlife Management Institute; 1973. 60 p.

Singer, F. J. Wild pig populations in the national parks. Environmental Management. 5(3): 263-270; 1981.

Stevens, V. The dynamics of dispersal in an introduced mountain goat population. Seattle, WA: University of Washington; 1983. 202 p. Ph.D. dissertation.

Stuart, T. W. Management models for human use of grizzly bear habitat. In: Transactions of the forty-third North American wildlife and natural resources conference; [date and location of conference unknown]. Washington, DC: Wildlife Management Institute; 1978: 434-441.

Tate, J. Techniques for controlling wild hogs in Great Smoky Mountains National Park: Proceedings of a workshop. Research/Resources Management Report SER-72. Atlanta, GA: U.S. Department of the Interior, National Park Service, Southeast Region; 1984. 87 p.

Taylor, J. N.; Courtenay, W. R., Jr.; McCann, J. A. Known impacts of exotic fishes in the continental United States. In: Courtenay, W. R., Jr.; Stauffer, J. R., Jr., eds. Distribution, biology, and management of exotic fishes. Baltimore: The Johns Hopkins University Press; 1984: 322-373.

Titus, J. R.; VanDruff, L. W. Response of the common loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. Wildlife Monograph 79. Washington, DC: Wildlife Management Institute; 1981. 59 p.

Van Ballenberghe, V.; Erickson, A. W.; Byman, D. Ecology of the timber wolf in northeastern Minnesota. Wildlife Monograph 43. Washington, DC: Wildlife Management Institute; 1975. 43 p.

Vanicek, C. D.; Kramer, R. H. Life history of the Colorado squawfish, *Ptychocheilus lucius*, and the Colorado chub, *Gila robusta*, in the Green River in Dinosaur National Monument, 1964-1966. Transactions of the American Fisheries Society. 98(2): 193-208; 1969.

Vannote, R. L.; Minshall, G. W.; Cummins, K. W.; [and others]. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 37(1): 130-137; 1980.

Varley, J. D. The status, ecology and management of the Yellowstone and Snake River finespotted cutthroat trout. West Yellowstone, WY: U.S. Department of the Interior, Fish and Wildlife Service; 1979. 8 p.

Varley, J. D. The use of restrictive regulations in managing wild salmonids in Yellowstone National Park, with particular reference to cutthroat trout. In: Walton, J. M.; Houston, D. B., eds. Olympic wild fish conference: Proceedings of a conference; 1983 March 23-25; Port Angeles, WA. [Publisher and place of publication unknown]; 1984: 145-146.

Varley, J. D.; Schullery, P. Freshwater wilderness: Yellowstone fishes and their world. Yellowstone National Park, WY: The Yellowstone Library and Museum Association, Yellowstone National Park; 1983. 133 p.

Walton, J. M.; Houston, D. B., eds. Olympic wild fish conference: Proceedings of a conference; 1983 March 23-25; Port Angeles, WA. [Publisher and place of publication unknown]; 1984. 308 p.

Warren, C. E. Toward classification and rationale for watershed management and stream protection. EPA-60013-79-059. Corvallis, OR: U.S. Environmental Protection Agency; 1979. 143 p.

White, P. Personal communication. Great Smoky Mountains National Park; 1980.

Wiersma, G. B.; Brown, K. W. Background levels of trace elements in forest ecosystems. In: Miller, P. R., tech. coord. Proceedings of the symposium on effects of air pollutants on Mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA. General Technical Report PSW-43. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 31-37.

Wright, R. G.; Hayward, P. National parks as research areas with a focus on Glacier National Park, Montana.

Bulletin of the Ecological Society of America. 66: 354-357; 1985.
Wright, S. Contemporary Pacific salmon fisheries management. North American Journal of Fisheries Management. 1(1): 29-40; 1981.

AUTHORS

Edward E. Starkey
Research Biologist
Cooperative Park Studies Unit
College of Forestry
Oregon State University
Corvallis, OR 97331

Gary L. Larson
Research Aquatic Biologist
Cooperative Park Studies Unit
College of Forestry
Oregon State University
Corvallis, OR 97331

WATER RESOURCES RESEARCH FOR WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

Raymond Herrmann
Owen R. Williams

ABSTRACT

The state of knowledge regarding watershed science as applied to wilderness or as related to the wilderness preservation concept is viewed relative to development of a strategy for implementation of long-term watershed studies. The substantial body of water resources research is applicable to understanding wilderness water management questions. Existing knowledge about issues of health and safety, technological development, visitor use, or ecological change is related to the need for new baseline knowledge about the consequences of various land-use activities. Impediments to wilderness research (access, measurement difficulties, experimental design), although considerable, are not overriding, particularly as our perception of consequence increases. The recommended approach to wilderness water resources studies, built on experiences borrowed from the National Park Service, National Science Foundation, and the U.S. Forest Service, requires establishment of a system of long-term watershed research sites. Implementation of this program ensures common measurements of physical, chemical, and biological parameters within the biosphere and hydrosphere, and of necessity includes sampling of precipitation, climate, soils, vegetation, and aquatic variables.

INTRODUCTION

Management strategies, to effectively protect the water resources in wildernesses, must be based on an understanding of the physical, hydrologic, and biologic processes which are actively shaping these systems and an appreciation of the potential for impact of various land-use activities on the water resources. Water resources, whether flowing or standing, represent an integration of the combined effects of all activities within the watershed. It is for this reason that researchers theoretically are able to look to the water resources to quickly determine the state of health of the entire watershed or ecosystem.

The purpose of this paper is to provide a brief overview, with examples of pertinent studies, of the state of knowledge about water and watershed science relevant to the wilderness setting and the wilderness preservation concept. The intent is to provide wilderness managers with an overview of existing water quantity and quality research knowledge and with a strategy for implementing long-term watershed research.

Since wildernesses are managed to preserve their wilderness character, land-use activities are generally restricted to recreation use such as hiking, skiing, backpacking, trail riding, and fishing; mechanized means of transport are generally prohibited. Although natural catastrophes, for example landslides and lightning-caused wildfire, can have serious impacts on the water resource, most past water resources concerns in wildernesses have centered on recreational use: protecting the health of the user and quantifying user impacts on water quality.

There is a substantial body of research that examines the effects of recreation on various attributes of wilderness, and on water resources. However, little research has specifically examined the effects of recreation on wilderness water resources. Therefore, much of what is presumed known about wilderness water resources is determined by analogy from studies in nonwilderness areas.

The most obvious reason for the paucity of water research in the wilderness setting is access. The very nature of wilderness connotes remoteness and isolation. While not all wildernesses are located in high, difficult-to-access mountain areas, most are generally rugged and remote. Further, access to research sites is difficult due to the limitations on use of modern technology and mechanized transport. Access can be more than just a difficult business causing discomfort to the researcher; it can also be personally hazardous. During the winter, access to certain mountain areas is often ill advised or virtually impossible.

A second reason for the lack of wilderness water research lies in the nature of resource impacts. It is often difficult to discriminate effects from background water quality levels. This complicates statistical analysis and limits the opportunity to infer statistically valid cause-effect relationships. The level of effect to be measured is often so small that measurement science is forced to its limits of detection. At this end of the detection spectrum, specific detailed steps are often required in the collection, transport, and measurement of certain variables. The necessary steps are often difficult and sometimes impractical or impossible in a wilderness setting.

A third reason for the lack of research may be found in the magnitude of consequence. Often, while an effect may be suspected or even measured, the consequence is not thought to be great or it presents no immediate hazard to either the visitor or the ecosystem.

A fourth reason is that there is limited opportunity for controlled experiments in the wilderness. Experimentation requires the deliberate manipulation of at least one variable affecting the system under study. Clearly, the influence of man is intentionally manifested in such an effort and to that degree it runs counter to the wilderness philosophy.

There are without doubt other reasons that could be enumerated for the lack of water resources research in wildernesses. However, these four reasons are likely the principal ones.

In view of the reasons listed, it is not surprising that water resources research techniques unique to the wilderness setting have not evolved. Most research efforts have been directed at using high-technology, lighter, portable (low power demand) equipment and obtaining data with as few site entries as possible. Often the development of technology limits the utility of the data collection. This is not to say that no suitable research techniques are available. Many research techniques have been developed and relationships established that can be and are profitably used in the wilderness setting; however, they were generally the result of studies in nonwilderness areas.

Similarly, a substantial body of research literature has been developed from studies of the effects on the water resource of industry; mining, milling, and minerals exploration; timber harvest, forest fertilization, road construction, and other silviculture-related activities; and hydropower, irrigation, and other water resource developments. Many of these studies have applicability to the wilderness setting, both in research techniques used and in relationships developed.

This body of knowledge, coupled with the research conducted in wilderness or wildernesslike environments, provides a broad understanding of the resource and a general understanding of its behavior. Perhaps more importantly it adds some insight into deficiencies in our understanding and identifies areas of additional research needs.

OVERVIEW OF PAST STUDIES

For the purposes of this overview, issues related to health and safety, technological development, visitor use, ecological change, and baseline understanding are emphasized. Impacts are thought of as internally or externally derived consequences, either direct or indirect, of recreationist activity, wildlife behavior, wildfire, anthropogenic, and certain natural biologic, hydrologic, and geologic processes.

The majority of existing water studies in wilderness and wildernesslike settings are associated with recreationist health and safety. This is not surprising because of the magnitude and perception of and immediacy of the potential impact, and the relative ease with which impacts may be identified. A number of studies have focused on the polluting effects of human and animal fecal disposal and increased contamination due to increased intensity of human use (Johnson and Middlebrooks 1975; Knudsen and others 1977; Christensen and others 1979; Varness and others 1978; Howard and Stanley-Saunders 1979).

Much of what was learned about water quality contamination in other areas is directly applicable to wilderness situations. The concern for health and safety has been elevated in recent years with the increase in either the incidence or the diagnosis of giardiasis. *Giardia* sp., a flagellated protozoan that inhabits the intestinal track of numerous mammals, causes gastrointestinal distress in humans. Of particular interest is illness associated with the consumption of untreated or poorly treated water in backcountry settings (Grant and Woo 1978; Black and others 1978; Craun 1979; Davies and Hibler 1979; Williams 1981; Suk 1983).

Studies of the health and safety aspects of wilderness water sources have not resulted in unequivocal answers; in fact more questions may be raised than are answered. Often we do not understand the natural environment well enough to evaluate our results. This has led to many studies of bacterial levels in areas with and without the influence of man (Bissonnette 1971; Stuart and others 1971; Walter and Bottman 1967; McFeters and others 1978; Erman 1979; Silverman and Erman 1979; Dasher and others 1981).

The remaining uncertainties suggest the need for studies of indicator bacteria themselves. Numerous studies have confirmed the large variability of bacterial organisms and have led to better understanding of animal and human contamination (Hendricks 1971; VanDonsal and Geldreich 1971; Skinner and others 1974; Geldreich 1976; Matson and others 1978; Varness and others 1978; White and others 1978; Grimes 1980; Gary 1982; Skinner and others 1984; Tunnicliff and Brickler 1984).

A subset of man's uses of wilderness is domestic livestock grazing. Studies have demonstrated that increased levels of bacteria can be associated with the presence of cattle (Kunkle and Meiman 1967; Kunkle 1970; Milne 1976; Stephenson and Street 1978; Skinner and others 1984), and that health hazards arise from livestock contamination (Willrich 1967; Diesch 1970; Swanson 1977). However, such contamination has been found to be short lived following discontinuation of grazing (Milne 1976).

The importance of human contributions to eutrophication is also recognized. Studies have been concerned with the potentially adverse impacts to dissolved oxygen and the nutrient content of a number of highly used wilderness lakes in the West (Barton 1969a, 1969b; King and Mace 1974; Erman 1979; Silverman and Erman 1979).

Other water resources impacts have received less attention in the wilderness context but are no less consequential. The effects of wildfire on water resources are an example. Wildfire can obviously be either natural or human caused. Further, management (suppression, control, or prescribed fire) can affect its consequences in the aquatic ecosystem. Fire research is not discussed here; however, a number of water resources impacts can be cited (Meginnis 1935; Copley and others 1944; Colman 1953; Rowe and others 1954; Sinclair and Hamilton 1955; Krammes 1960; Crouse 1961; Glendening and others 1961; Rich 1962; Krammes and DeBano 1965; Pase and Ingebo 1965; DeBano and Krammes 1966; DeBano and others 1970; Berndt 1971; Brown 1972; DeByle and Packer 1972; Helvey 1973; Rice 1974; Anderson and others 1976; Dyrness 1976; Helvey and others 1976; Wright 1976; Wright and others 1976; Campbell and others 1977; Davis 1977). The duration of these effects has been shown to vary substantially. Changes in summer water temperatures, streamflow, and mineral export were identified in a stream draining a watershed burned 45 and 36 years previously (Albin 1979). Only minor changes in the hydrology, chemistry, and phytoplankton biology of a wilderness lake were noted using paleolimnologic techniques 2 years after the watershed was burned (Bradbury and others 1975).

Mining activities occurring in areas prior to their declaration as wilderness can have latent potential effects. Some of the national parks in Alaska have active mining operations. Austin and Munteanu (1984) described changes in phytoplankton and zooplankton communities in a lake associated with mine tailing effluent. In general, a large body of literature related to mine effects and reclamation exists but is not referenced here.

Threats to wilderness water resources from events taking place outside wildernesses can be related to a number of activities, including water resource developments and operations, weather modification, air pollution, and dynamic natural biologic, hydrologic, and geologic processes.

We have seen a national and international increase in the amount of study directed at wet and dry atmospheric deposition. The public and scientific interest that has been produced in recent years as a result of ecosystem impacts in Europe, Canada, and the Northeastern United States is likely to continue for several more years. The scope of postulated effects from atmospheric deposition is broad. The impacts to water, both direct and indirect, have the potential of causing great change within wilderness water resources.

Much literature has been developed in Europe, Canada, and the United States covering the acid rain atmospheric deposition issue. Also, a number of good comprehensive reviews with bibliographies exist (USEPA 1985). A number of studies demonstrate that acid precipitation is occurring in wilderness areas (Lewis and Grant 1979, 1980; Huebert and others 1982). Recent findings also demonstrate the potential susceptibility of remote areas to atmospheric deposition (Herrmann and Baron 1980; Crisman and others 1980; Baron 1983; Gibson and others 1983; Welch and others 1984; Norton and others in press), and the ongoing U.S. Environmental Protection Agency lake survey will provide new knowledge about the chemical state of western wilderness waters. Studies have demonstrated increased heavy metal deposition in lake sediments (Galloway and Likens 1979) and that stream systems were maintaining cation stability by degrading soil buffer systems (Shaffer and Galloway 1982). A number of studies aimed at understanding catastrophic change in the natural chemical environment have looked to wilderness following the eruption of Mount St. Helens for representative natural study sites (Fahey 1979; Collins and others 1981; Dahm and others 1981; Lehre and others 1981; Staley and others 1982; Wissmar and others 1982; Welch and others 1984).

A wilderness lake in Canada was studied to determine the origin of its nonvolatile hydrocarbon content (Starnes and Brown 1976). The authors concluded that the hydrocarbons were of plant and animal, not human, origin. Other researchers have found natural sources of lake acidification (Patrick and others 1981; Helvey and others 1982). However, the available knowledge is limited.

The development and utilization of water resources, both existing and potential, offer the greatest possibility for direct impact to wilderness water resources values. The closing of Glen Canyon Dam has resulted in a long-term change in the hydrologic and geomorphic equilibrium of the Colorado River. Turner and Karpiscak (1980) identified changes in sediment load and discharge regime that have influenced the formation and destruction of riverbanks, bars, and terraces. They also observed dramatic changes in the amount of vegetation occupying sediment deposition sites with associated reductions in channel width.

A first-of-its-kind study has been initiated in the Holy Cross Wilderness in Colorado where construction is underway on a legislatively permitted transmountain water diversion within the wilderness boundary. The study (Cities of Aurora and Colorado Springs 1985) is intended to monitor streamflow, fish habitat, channel morphology, wetlands, and ground water to develop plans for mitigation of impacts, should any occur.

The potential for water development in the high mountain areas of many western wildernesses has long been recognized. Martinelli (1975) identified the potential to increase water yield through increasing snow deposition in alpine areas. Methods described include snow fences, terrain modification, intentional avalanching, and glacier building. Further, researchers have demonstrated that the melt rate of glaciers and snowfields can be modified through the application of various dusting agents (Slaughter 1966; Kotlyakov and Dolgushin 1972; Regelin and Wallmo 1975).

A major issue in wilderness management is weather modification. It has been estimated that the Upper Colorado River basin could experience an average increase in water yield of 0.9 to 1.3 million acre-feet per year through weather modification (Foehner 1977). In addition, it is felt that this could be done with little or no significant water quality degradation or stream channel effects (Foehner 1977). Questions remain, however, as to the long-term impacts on channels and lakes if a long-term net increase or decrease in precipitation were to occur. Knight and others (1979) demonstrated the potential for unmeasured effects that could arise as a consequence of increased water flow through soils and the need for further study.

One of the paramount values of wilderness is its role as a natural history record. As such, it serves as a barometer of environmental change. Whether of natural or human origin, change may be seen as the response of sensitive ecosystems to disturbances. Long-term study of water bodies found within wilderness is needed to: (1) identify and mitigate use-related impacts and (2) provide an early warning of future damages so that preventive or corrective actions can be applied to problem sources located outside wilderness.

To develop basic knowledge, data gathering studies have been implemented (Ghirelli and others 1977; Tunnicliff and Brickler 1984). Research into the geomorphology of channel features (Leopold 1975) exemplifies the approach to understanding natural hydrologic systems. Studies aimed at protecting California alpine lakes and streams from user impacts (Flowers 1974; Kawaratani and Perrine 1975; Silverman and Erman 1979) examined baseline conditions for water chemistry, physical parameters, bacteria, plankton, and periphyton. Similar efforts in the East by Silsbee and Larson (1982) in the Great Smoky Mountains National Park included studying physical, chemical, and bacteriological water quality parameters for a year to determine the factors most important in controlling water quality and develop baseline information for long-term water quality monitoring and aquatic research.

In the Sierra Nevada Mountains of California, Melack and others (1982) intensively evaluated the buffer capacity of 23 alpine lakes; most were determined to be very weakly buffered. A high susceptibility to impact from acid deposition was therefore concluded. A similar finding was presented by Turk and Adams (1983) for lakes in the Flat Tops Wilderness of Colorado. After intensive study of 27 lakes, the authors concluded that approximately 370 lakes in the wilderness were sensitive to acidification.

Johnson (1981) measured unpolluted waters in southeastern Alaska to determine natural acidity. The data, he noted, can serve as a background for comparison with future measurements of water acidity. Similarly, Watling (1979) looked at wilderness lakes to establish background levels of trace and major metals. On a larger scale, Brown (1981) discussed the 33 designated biosphere reserves where samples of water and other components of the natural environment could be analyzed for organic and heavy metal contaminants delivered from the atmosphere.

The wide concern over the effects of atmospheric deposition on wilderness water resources values has also prompted a number of pollutant-monitoring baseline studies. Wiersma and others (1984) noted finding commonly reported background levels of trace elements, sulfate, and nitrate in remote areas of three National Parks: Great Smoky Mountains, Olympic, and Glacier.

Chemical data were collected for comparison of atmospheric, hydrologic, and biologic factors to baseline conditions. Substances entering the parks are perceived to have an unknown effect on the preserves' integrity, and decisions on acceptable levels of additional pollutants must be based on knowledge of ambient levels and the nature of effects. Careful field sampling techniques and high-resolution laboratory analyses were employed to assess levels, patterns, and trends of environmental contaminants. The use of multielemental analysis techniques has increased the speed of analysis and significantly reduced costs. These methods greatly increase the probability of detecting unnatural changes in chemical cycles and of understanding unusual chemical results. Comparative water chemistry data from Great Smoky Mountains, Glacier, and Olympic National Parks can be employed to establish relative levels of contamination (Wiersma and Brown 1979).

Installation of uniform wetfall/dryfall atmospheric deposition collectors in 28 parks, 11 of which are park/biosphere reserves, was accomplished as a part of cooperative efforts between the National Park Service, Man and the Biosphere Program of UNESCO, National Atmospheric Deposition Program (NADP), and the National Acid Precipitation Assessment Program (NAPAP) between 1980 and 1985. The network includes over 150 stations and presently provides a uniform controlled framework for sampling, data analysis, and quality control of physical and chemical data that is being applied nationally. Data from these stations provide the National Park Service and others with the ability to study what and how substances are impinging on natural resources and have resulted in the first tangible comparative data set for U.S. biosphere reserves (Herrmann 1982).

Understanding Past Research: The Present

Wilderness recreation has been said to be increasing faster than most forms of forest recreation and considerably faster than the national population growth rate (Jones 1975). The potential for impacts to wilderness water resources grows yearly, and can be expected to continue into the foreseeable future. The wilderness manager must therefore be provided with the means and the opportunity to identify and prevent adverse water resources impacts. Where impacts do occur, workable mitigative measures must be available.

The limited knowledge about wilderness is greatly augmented through analogy; pertinent nonwilderness studies can be utilized to some degree to help managers protect wilderness water resources. For example, Berry and others (1983) described six management strategies applied to commercial white-water rafting, specifically, river recreation management plans, land use controls, use limits, access permits, guide certification, and flow regulation. Recreationist information and education programs have been expanded as a consequence of research findings. As a result, recreationists have been alerted to potential health hazards and instructed in methods to reduce such hazards (Tunnicliff and Brickler 1984). Other applications of research findings include changes in backcountry waste disposal requirements, indirect methods for the estimation of water quality (Tunnicliff and Brickler 1984), recreationist registration, and group size limitations (Cieslinski 1977). The research on atmospheric deposition effects and processes has been of value in permit hearings for locating new air-polluting facilities.

Analysis of this current knowledge leads to a realization of the need for baseline data collection. All the impediments to wilderness research discussed (access, measurement difficulties, magnitude of consequence, and experimental design) are important considerations; however, as magnitude of consequences becomes more substantial, in real terms or in our perception, the likelihood increases that the obstacles will be overcome.

The direction wilderness or natural area water resources research is likely to take in the future is difficult to predict. The need for additional scientific inquiry into the effects of atmospheric deposition on wilderness water resources seems to be evident, and results from the potential magnitude of both environmental effects and remedial cost, both on and off site. Reconnaissance surveys and baseline studies are evolving from the accelerated study of atmospheric deposition research.

The potential for water resources impacts due to water resources development or weather modification is at present unknown. Prediction of impacts resulting from development of water resources will require a better understanding of the mechanisms involved and their interrelationship with sensitive ecosystems.

The need for an effort in trend monitoring is beginning to surface in some areas. Such an activity will be of help in detecting environmental change resulting from increased recreational use and in defining carrying capacities.

The scarcity of research related to wilderness water resources will probably continue—until that time and in those places where the risks finally become so great that our lack of knowledge may result in the loss of the resource.

A STRATEGY FOR THE FUTURE

Reiteration of wilderness-related water resources research and monitoring activities is valuable. The important aspects of this knowledge increase our understanding of natural ecosystems and identify information needs for management of remote areas.

A number of approaches might be initiated to enhance our understanding of wilderness water resources or, more generally, wilderness resources. One preferred choice is a coordinated effort to establish a system of long-term ecological research sites at the watershed level. The remainder of the discussion revolves around concepts supporting this approach and the presentation of a sample long-term research program.

The watershed can be hypothesized within this larger ecological arena as an integrator of human and natural change. Alteration of fundamentally natural systems continues in the broader sense for the benefit of humans and their technology. Preserves as wilderness exist within this technological arena and are not isolated from the effects of this encroachment. Thus, the importance of wilderness research has been recognized. One cannot, however, detect change without having a baseline and cannot understand change without a knowledge of what is natural.

One can argue that a number of useful programs that are not uniquely wilderness form a broad definition of wilderness research that can lead toward an integrated approach. The proof of this argument depends on ongoing and future research that will enable the identification of the hypotheses. The program of remote area (wilderness) monitoring and research that is recommended has been applied in a limited number of cases (Wiersma 1979; Herrmann and Baron 1981; Baron 1983; Stottlemeyer 1984; Parsons and Graber 1985).

Analysis of combined hydrologic, biologic, and physical data sets has proved to be a good approach to develop a better understanding of remote natural (wilderness) resources. Interactive monitoring activities have included: (1) pollutant inputs and cycling data, including precipitation analysis; (2) climatic data; (3) permanent plot systems for monitoring changes in plant communities, soils, and soil waters, including chemical, physical, and biological change; (4) serial collection of chemical and biological data; and (5) population monitoring of select aquatic and terrestrial species. The benefits anticipated from continuing these activities in other remote or wilderness sites will include an increased ability to respond to new requirements, anticipate changing information requirements, understand the processes affecting resources, and evaluate new activities.

A preserve is dynamic, not static, and while we may not immediately notice slow, long-term, unexpected changes, it is important to know whether these changes are natural or human caused. We all must be concerned about today's issues, but through a coordinated set of watershed studies we can build a foundation for management of the entire ecosystem. In this manner we develop the mechanisms and the abilities to respond to the issues of tomorrow.

The experience of the National Park Service in implementing a long-term research program on the effects of acid precipitation on natural ecosystems and in developing pilot pollutant monitoring studies leads to the presentation of the following example as a point of departure for implementation of long-term wilderness watershed studies. These activities, when meshed with efforts of the National Science Foundation, Forest Service, and others can be the beginning of a national program for long-term ecological measurements and baseline studies in wilderness and equivalent remote natural areas.

Three sites were chosen to begin long-term watershed research related to atmospheric deposition during fiscal year 1983: Isle Royale, Rocky Mountain, and Sequoia National Parks. Olympic National Park was added in 1984. Each of these parks has been designated an International Biosphere Reserve, protects an example of a pristine or near-pristine ecosystem, and has a scientific research infrastructure and a history of use as a living scientific laboratory that enhances and benefits from the research proposed here.

Specific research was designed to meet the need for long-term data on the dynamics of undisturbed ecosystems and places emphasis on the study of ecological processes at the watershed level, using timeframes exceeding those commonly used in manipulative biological or ecosystems research. Each uses a standardized set of core measurements (table 1) while focusing on one or more specific areas of research. For Isle Royale the existing program of research was expanded to focus on the effects of acid deposition on boreal watershed/lake ecosystems. Within Rocky Mountain National Park the program emphasizes impacts on soil and water chemical processes. In Sequoia the research examines vegetation and aquatic community response across a broad elevation gradient. Finally, at Olympic there is an established background site approximating the lowest levels of known atmospheric pollutants in the continental United States.

Table 1.—Desirable measurements for long-term wilderness monitoring and research

Field to be measured	Data collected	Frequency	Methods
Precipitation (chemistry)	Deposition chemistry	Weekly	Bigelow 1982; NADP 1984
	Wet	Weekly	Bigelow 1982; NADP 1984
	Snow	Monthly	Herrmann and others 1982
	Dry		Protocol being developed
	Bulk collections	Weekly	Bigelow 1982; NADP 1984; Herrmann and others 1982
	Trace metals		EPA 1985
Climate	Windspeed and direction, humidity (or equivalent), temperature, incident solar radiation, precipitation amount	Continuous on site	Herrmann and others 1982
Vegetation	Permanent plots, phenology	Resurvey 5 years	Parsons and Graber 1984
Soils	Plots in a manner consistent with vegetation analysis	Remeasure 5 years	Herrmann and others 1982
Hydrology and aquatic studies	Temperature	Weekly (for 1 year)	Herrmann and others 1982
	Chemistry (major cations and anions)	Seasonal/event	EPA 1985
	Stream discharge	Continuous	Rantz 1982
	Lake stage (inflow-outflow measurements as needed for mass balance)	Continuous	Herrmann and others 1982
	Ground water mass balance (inputs/outputs)	One time—seasonal	
	Ground water (chemistry characterization)	Repeat 5 years	
	Characterize aquatic system and establish baseline of indicator species	5 years	Herrmann and others 1982
Paleolimnology	Sediment cores (diatom and heavy metals analysis)	One time	Baron and others 1985
	Pollen analysis, if possible	One time	Baron and others 1985

Interagency and interinstitutional cooperation on research and monitoring activities continues to involve state agencies, several universities, and federal agencies. The program structure incorporates what has been learned from the experiences of the National Science Foundation and reflects the thinking developed during formation of the National Science Foundation's Long-term Ecological Research Program (NSF 1977, 1979) and Man and the Biosphere monitoring protocols (USMAB 1979). Whole system studies resulting from this initiative are thought to be particularly useful for the partitioning and comparison of complex cause and effect relationships. In addition, the assessment, evaluation, and understanding of how pristine natural areas respond to human-driven change provide a predictive capability about potentially irreversible long-term changes.

A number of the objectives to be met directly support the goals of long-term ecological/watershed research: (1) detection of chemical changes within each ecosystem at the watershed level; (2) detection of biological change within each ecosystem at the watershed level; (3) establishment of nationally representative baseline sites; (4) partitioning of cause and effect relationships of long-term ecosystem change; (5) evaluation of how different unmanipulated natural sites will respond to acidification; (6) establishment of an early warning system for measuring ecosystem response.

The linkage by design of physical and ecological effects monitoring activities and baseline studies of natural systems at the watershed level pertains directly to our ability to test hypotheses.

Recommended Long-Term Measurement Activities

A program for continued long-term measurements provides: useful information on research questions, for improved management of wilderness and other preserved units, and for comparative studies among sites comprising the cooperative network. The approach described here presumes that ecological change is representable by a select number of physical and ecological variables. The core measurement strategy detects spatial and temporal differences of the measured variables. Site-specific long-term data sets employing standardized techniques of measurement are required for interecosystem comparisons or regional analogy. The core measurements program is designed to meet the following measurement criteria:

-Techniques will not be changed unless a new technique can be calibrated against the old.

-Sampling intervals should be within the timeframe of known biologic events.

-For descriptive studies or map measurements, scale and archiving will be compatible.

-Samples such as botanical materials, sediment cores, and known plankton or benthos will be cataloged and stored using standard museum procedures.

-Dynamic (physical or biological) measurements will employ techniques that can be accurately repeated.

-Techniques will allow partitioning of change into trends or cyclic events.

The study unit for long-term ecological measurements of effects is the watershed. A study site (wilderness, reserve) may consist of multiple watersheds, but within each watershed a number of physical and biological data sets or records are required to characterize the biota, climate, watershed, hydrology, geology, and the physical and chemical characteristics of soils, water, and the atmosphere. Together the data collections comprise a series of desirable baseline studies (Herrmann and others 1978; Franklin and Krugman 1979; Wiersma 1979; Wiersma and Brown 1979; Wiersma and others 1979; Hemstrom and Franklin 1981).

Repetitive measurements common to all sites include precipitation, climate, soils, vegetation, hydrology, aquatic samples, and paleolimnology (table 1). The proposed sets of measurements may not be appropriate to all areas or situations. They are meant as a beginning and a point of departure.

CONCLUSIONS

The focus of wilderness research should be an integrated program of long-term ecological research that has its foundation in the watershed. The hope is that the holistic design of this program will focus research activities toward a common objective that results in the development of data required for improved resource management and for solution of the complex research questions related to remote area or wilderness management. In the past, research, inventory, and monitoring were thought of separately. This program fuses the three into a directed program for the collection of data needed to test hypotheses relative to human contributions to long-term ecological change within wilderness environments.

This paper has covered the state of wilderness research as it relates to water resources. In the past the bulk of interest was health and safety and recreation, although for various reasons not a great deal of research was actually carried out in wilderness. A number of ongoing activities that have a holistic watershed approach to wilderness research were reviewed. Relying on the lessons learned from these activities, which have mainly been supported by the National Park Service, the National Science Foundation, and the U.S. Forest Service, a strategy for future wilderness/remote natural area research was presented.

For a program resulting from the application of these suggestions to be fully accepted, many of us must begin to think in terms of the knowledge required for long-term wilderness preservation. We again challenge present and future wilderness managers/land managers to utilize the foregoing concepts, concepts that will help to solve problems and achieve goals. The requirements facing us today are not new. The challenge is to perceive humans as a part of their environment and to meet our preservation commitments in a world of increasingly complex and changing objectives.

REFERENCES

Albin, D. P. Fire and stream ecology in some Yellowstone Lake tributaries. California Fish and Game. 65(4): 216-238; 1979.

Anderson, H. D.; Hoover, M. D.; Reinhard, K. G. Forest and water: effects of forest management on floods, sedimentation, and water supply. General Technical Report PSW-18. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1976. 115 p.

Austin, A.; Munteanu, N. Evaluation of changes in a large oligotrophic wilderness park lake exposed to mine tailing effluent for 14 years: the phytoplankton. Environment Pollution (Series A). 33: 39-62; 1984.

Baron, J. Comparative water chemistry of four lakes in Rocky Mountain National Park. Water Resources Bulletin. 19(G): 896-902; 1983.

Baron, J.; Norton, S. A.; Beeson, D. R.; Herrmann, R. Sediment diatom and metal stratigraphy from Rocky Mountain lakes with special reference to atmospheric deposition. Canadian Journal of Fisheries and Aquatic Sciences; [in press].

Barton, M. A. Water pollution in remote recreational areas. Journal of Soil and Water Conservation. 24(4): 132-134; 1969a.

Barton, M. A. Waters of the canoe country. Naturalist. 20(1): 42-47; 1969b.

Berndt, H. W. Early effects of forest fire on streamflow characteristics. Research Note PNW-148. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1971. 9 p.

Berry, D.; Cox, C.; Wolff, P. Managing rafting river. Water Spectrum. 15(1): 10-17; 1983.

Bigelow, D. S., ed. National Atmospheric Deposition Program instruction manual: site operation. Fort Collins, CO: Colorado State University, Natural Resource Ecology Laboratory; 1982. 30 p.

Bissonnette, G. K. A microbiological and chemical investigation of effects of multiple use of high mountain watersheds. Bozeman, MT: Montana State University; 1971.

Black, R. E.; Horwitz, M. A.; Craun, G. F. From the Center for Disease Control: outbreaks of water borne disease in the United States. Journal of Infectious Diseases. 137(3): 370-374; 1978.

Bradbury, J. P.; Tarapchak, S. J.; Waddington, J. C. B.; Wright, R. F. The impact of a forest fire on a wilderness lake in northeastern Minnesota. Stuttgart, West Germany: International Association of Theoretical and Applied Limnology. Verh. Internat. Verin. Limnol. 1975: 875-883.

Brown, J. A. H. Hydrologic effects of a brushfire in a catchment, southeastern New South Wales. Journal of Hydrology. 15: 77-96; 1972.

Brown, K. W. Pollutant monitoring in the Olympic National Park biosphere reserve. Environmental Monitoring and Assessment. 1: 37-46; 1981.

Campbell, R. E.; Baker, M. B., Jr.; Ffolliott, P. F.; [and others]. Wildfire effects on a ponderosa pine ecosystem Arizona case study. Research Note RM-191. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977. 12 p.

Christensen, H. H.; Pacha, R. E.; Varness, K. J.; Lapen, R. F. Human use in a dispersed recreation area and its effect on water quality. In: Ittner, Ruth; [and others], eds. Recreational impact on wildlands: Conference proceedings; 1978 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 107-110.

Cieslinski, T. J. Allagash Wilderness waterway. In: Proceedings, river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 117-120.

Cities of Aurora and Colorado Springs [Colorado]. Homestake phase II water quality maintenance and monitoring plan. 1985. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, White River National Forest, Glenwood Springs, CO. 5 p.

Collins, B.; Dunne, T.; Lehre, A. K. Sediment influx to the Toutle River from erosion of tephra, May 1980-May 1981. In: Mount St. Helens: effects on water resources: Proceedings from the conference; 1981 October 7-8; Jantzen Beach, OR. Report 41. Pullman, WA: Washington State University and State of Washington Water Research Center; 1981: 82-97.

Colman, E. A. Fire and water in southern California's mountains. Miscellaneous Paper No. 3. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1953.

Copley, T. L.; Forrest, L. A.; [and others]. Investigation in erosion control and reclamation: eroded land in the Central Piedmont Conservation Experiment Station. Technical Report 873. Statesville, NC: U.S. Department of Agriculture; 1944. 66 p.

Craun, G. F. Waterborne outbreaks of giardiasis. In: Jakubowski, W.; Hoff, J. C., eds. Waterborne transmission of giardiasis: Proceedings of a symposium; 1978 September 18-20; Cincinnati, OH. EPA-600/9-79-001. Cincinnati, OH: U.S. Environmental Protection Agency; 1979.

Crisman, T. L.; Schulze, R. L.; Brezonik, P. L.; Bloom, S. A. Acid precipitation: the biotic response in Florida lakes. In: Proceedings, international conference on ecological impact of acid precipitation; 1980 March 11-14; Sandefjord, Norway. Oslo, Norway: SNSF Project; 1980.

Crouse, R. P. First-year effects of land treatment on dry streamflow after a fire in southern California. Research Note 191. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1961. 5 p.

Dahm, C. N.; Baross, J. A.; Lilley, M. D.; Ward, A. K.; Sedell, J. R. Lakes in the blast zone of Mount St. Helens: chemical and microbial responses following the May 18, 1980, eruption. In: Mount St. Helens: effects on water resources: Proceedings from the conference; 1981 October 7-8; Jantzen Beach, OR. Report 41. Pullman, WA: Washington State University and State of Washington Water Research Center; 1981: 82-97.

Dasher, D. H.; Urban, L. V.; Dvoracek, M. J.; Fish, E. B. Effects of recreation on water quality in Guadalupe Mountains National Park. Transactions of the American Society of Agricultural Engineers. 24: 1181-1187; 1981.

Davies, R. B.; Hibler, C. P. Animal reservoirs and cross species transmission of giardia. In: Jakubowski, W.; Hoff, J. C., eds. Waterborne transmission of giardiasis: Proceedings of a symposium; 1978 September 18-20; Cincinnati, OH. EPA-600/9-79-001. Cincinnati, OH: U.S. Environmental Protection Agency; 1979.

Davis, J. D. Southern California reservoir sedimentation. In: Proceedings of American Society of Civil Engineers fall convention and exhibition; 1977 October 17-21; San Francisco, CA. Preprint #3017. New York: American Society of Civil Engineers; 1977. 25 p.

DeBano, L. F.; Krammes, J. S. Water repellant soils and their relationship to soil temperatures. International Association of Scientific Hydrologists. 11(2): 14-19; 1966.

DeBano, L. F.; Mann, L. D.; Hamilton, D. A. Translocation of hydrophobic substances into soil by burning organic litter. Soil Science Society of America Proceedings. 34: 130-133; 1970.

DeByle, N. V.; Packer, P. E. Plant nutrient and soil losses in overland flow from burned forest clearcuts. In: Watersheds in transition: Proceedings of a symposium; 1972 June 19-22; Fort Collins, CO. AWRA #14. Urbana, IL: American Water Resources Association; 1972: 296-307.

Diesch, S. L. Disease transmission of waterborne organisms of animal origins. In: Willrich, T. L.; Smith, G. E., eds. Agricultural practices and water quality. Ames, IA: Iowa State University Press; 1970: 265-285.

Dyrness, C. T. Effect of wildfire on soil wettability in the High Cascades of Oregon. Research Paper PNW-202. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1976. 18 p.

Erman, D. C. The impact of people on mountain wilderness lakes. California Agriculture. 1979 May: 25.

Fahey, T. J. Changes in nutrient content of snow water during outflow from Rocky Mountain coniferous forest. OIKOS. 32(3): 422-428; 1979.

Flowers, E. S. Measurement and management aspects of water toxicology: the Malibu watershed, a mixed residential and wilderness area. Davis, CA: University of California, Water Resources Center; 1974. 48 p.

Foehner, O. H. Weather modification: a major resource tool. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation, Division of Atmospheric Water Resources Management; 1977. 13 p.

Franklin, Jerry F.; Krugman, Stanley L., coords. Selection, management and utilization of biosphere reserves: Proceedings of the United States-Union of Soviet Socialist Republics symposium on biosphere reserves; 1976 May; Moscow, USSR. General Technical Report PNW-82. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 308 p.

Galloway, J. N.; Likens, G. E. Atmospheric enhancement of metal deposition in Adirondack lake sediments. Limnology and Oceanography. 24(3): 427-433; 1979.

Gary, H. L. Stream water quality in a small commercial campground in Colorado. Journal of Environmental Health. 45(1): 5-12; 1982.

Geldreich, E. E. Fecal coliform and fecal streptococcus density relationships in waste discharges and receiving waters. Critical Review of Environmental Control. 6: 349-368; 1976.

Ghirelli, R. P.; Lo, P. M.; Marler, L. Bacterial water quality in wilderness areas. Contribution No. 162. Davis, CA: University of California, Water Resources Center; 1977. 50 p.

Gibson, J. H.; Galloway, J. N.; Schofield, C.; [and others]. Rocky Mountain acidification study. FWS/OBS-80/40.17. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1983. 138 p.

Glendening, G. E.; Pase, C. P.; Ingebo, P. Preliminary hydrologic effects of wildfire in chaparral. In: Modern techniques in water management: Proceedings of the fifth annual Arizona watershed symposium; 1961 September 21; Phoenix, AZ. Phoeniz, AZ: State Land Department, Watershed Management Division; 1961: 12-15.

Grant, D. R.; Woo, P. T. K. Comparative studies of *Giardia* species in small mammals in southern Ontario. In: Prevalence and identity of the parasites with a taxonomic discussion of the genus. Canadian Journal of Zoology. 56: 1348-1359; 1978.

Grimes, D. J. Bacteriological water quality effects of hydraulically dredging contaminated Upper Mississippi River bottom sediment. Applied Environmental Microbiology. 39: 782-789; 1980.

Helvey, J. D. Watershed behavior after forest fire in Washington. In: Proceedings, agriculture and urban considerations in irrigation drainage; 1983 August 22-24; Fort Collins, CO. New York: American Society of Civil Engineers; 1973: 403-422.

Helvey, J. D.; Kunkle, S. H.; DeWalle, D. Acid precipitation: a review. Journal of Soil and Water Conservation. 37: 143-148; 1982.

Helvey, J. D.; Tiedemann, A. R.; Fowler, W. B. Some climatic and hydrologic effects of wildfire in Washington State. In: Proceedings, Tall Timbers Fire Ecology Conference No. 15; 1967 May 4-17. Tallahassee, FL: Tall Timbers Fire Ecology Laboratory; 1976: 201-222.

Hemstrom, M. A.; Franklin, J. F., eds. Proceedings of the second United States-Union of Soviet Socialist Republics symposium on biosphere reserves; Everglades National Park, FL. Washington, DC: U.S. Department of the Interior, National Park Service; 1981. 271 p.

Hendricks, C. W. Increased recovery rate of Salmonellae from stream bottom sediment versus surface waters. Applied Microbiology. 21: 279-380; 1971.

Herrmann, R. Obtaining baseline knowledge for U.S. biosphere reserves. In: Towards the biosphere reserve: exploring the relationship between parks and adjacent lands: Proceedings of an international symposium; 1982 June 22-24; Kalispell, MT. Washington, DC: U.S. Department of the Interior, National Park Service; 1982: 103-114.

Herrmann, R.; Baron, J. Aluminum mobilization in acid environments, Great Smoky Mountains National Park. In: Drablos, D.; Tollon, A., eds. Proceedings of the international conference on the ecological impact of acid rain; 1980 March 11-14; Sandefjord, Norway. Oslo, Norway: Jolis. Grefslie Trykkeri A/S, Mysen; 1980: 218-219.

Herrmann, R.; Baron, J. Environmental monitoring in national park biosphere reserves. In: Hemstrom, M. A.; Franklin, J. F., eds. Proceedings of the second United States-Union of Soviet Socialist Republics symposium on biosphere reserves; 1980 March 10-15; Everglades National Park, FL. Washington, DC: U.S. Department of the Interior, National Park Service; 1981: 254-262.

Herrmann, R.; Baron, J.; Parsons, D. J.; Stottlemeyer, J. R. A proposal: the effects of acid precipitation—long-term ecological measurements in representative national parks. 1982. Unpublished manuscript on file at: National Park Service, Water Resources Division, Fort Collins, CO.

Herrmann, R.; Stoneburner, D. L.; Larson, G. L.; Mathews, R. C.; Burge, R. E. Environmental monitoring for remote natural areas, Great Smoky Mountains National Park. In: Pecora IV. Proceedings of the symposium: application of remote sensing data to wildlife management; 1970 October 10-12; Sioux Falls, SD. Washington, DC: National Wildlife Foundation; 1978: 306-311.

Howard, G. E.; Stanley-Saunders, B. A. Impacts of recreation activities associated with streams: a problem analysis. Clemson, SC: Clemson University, Department of Recreation and Park Administration; 1979. 58 p.

Huebert, B. J.; Norton, R. B.; Bollinger, M. J.; [and others]. Gas phase and precipitation acidities in the Colorado Mountains. In: Proceedings, international symposium on hydrometeorology; 1982 June 13-17; Denver, CO. Bethesda, MD: American Water Resources Association; 1982: 17-23.

Johnson, B. A.; Middlebrooks, E. J. Water quality as an approach to managing recreational use and development on a mountain watershed: South Fork of the Ogden River, Ogden Valley area. PRWA 21-1. Logan, UT: Utah State University, College of Engineering, Water Resources Lab; 1975. 84 p.

Johnson, D. W. The natural acidity of some unpolluted waters in southeastern Alaska and potential impacts of acid rain. Water, Air and Soil Pollution. 16: 243-252; 1981.

Jones, D. B. An optimizing reservation system for backcountry campsites. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 137 p.

Kawaratani, R. K.; Perrine, R. L. Wilderness water quality: Bishop Creek baseline study, 1974. Contribution No. 150. Los Angeles: University of California, Water Resources Center; 1975. 231 p.

King, J. G.; Mace, A. C. Effects of recreation on water quality. Journal of Water Pollution Control Federation. 46(11): 2453-2459; 1974.

Knight, D. H.; Weaver, S. W.; Starr, C. R.; Romme, W. H. Differential response of subalpine meadow vegetation to snow augmentation. Journal of Range Management. 32(5): 356-358; 1979.

Knudsen, A. B.; Johnson, R. R.; Johnson, K.; Henderson, N. R. A bacteriological analysis of portable toilet effluent at selected beaches along the Colorado River, Grand Canyon National Park, AZ. In: River recreation management and research: Symposium proceedings. General Technical Report NC-281. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 290-295.

Kotlyakov, V. M.; Dolgushin, L. D. Possibility of artificial augmentation of melting by surface dusting of glaciers (results of Soviet investigations). In: The role of snow and ice in hydrology: Proceedings of the Banff symposia; Vol. 2. Paris, France: UNESCO-WRO-IAHS; 1972: 1421-1426.

Krammes, J. S. Erosion from mountain side slopes after fire in southern California. Research Note No. 171. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1960. 8 p.

Krammes, J. S.; DeBano, L. F. Soil wettability: a neglected factor in watershed management. Water Resources Research. 1: 283-386; 1965.

Kunkle, S. H. Sources and transport of bacterial indicators in rural streams. In: Proceedings, symposium on the interdisciplinary aspects of watershed management; 1970 August 3-6; Bozeman, MT. Bozeman, MT: American Society of Civil Engineers, Montana State University; 1970. 28 p.

Kunkle, S. H.; Meiman, J. R. Water quality of mountain watersheds. Hydrology Paper No. 21. Fort Collins, CO: Colorado State University; 1967. 53 p.

Lehre, A. K.; Collins, B.; Dunne, T. Preliminary post-eruption sediment budget for the North Fork Toutle River drainage, June 1980-May 1981. In: Mount St. Helens: effects on water resources: Proceedings from the conference; 1981 October 7-8; Jantzen Beach, OR. Report 41. Pullman, WA: Washington State University and State of Washington Water Research Center; 1981: 215-234.

Leopold, L. B. The rapids and the pools—Grand Canyon. In: The Colorado River region and John Wesley Powell. Professional Paper 669-D. Washington, DC: U.S. Department of the Interior, Geological Survey; 1975: 131-145.

Lewis, W. M.; Grant, M. C. Changes in the output of ions from a watershed as a result of the acidification of precipitation. Ecology. 60(6): 1093-1097; 1979.

Lewis, W. M.; Grant, M. C. Acid precipitation in the western United States. Science. 207: 176-177; 1980.

Martinelli, M. Water-yield improvement from alpine areas: the status of our knowledge. Research Paper RM-138. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 16 p.

Matson, E. A.; Horner, S. G.; Buck, J. D. Pollution indicators and other microorganisms in river sediment. Journal of Water Pollution Control Federation. 50: 12-19; 1978.

McFeters, G. A.; Stuart, S. A.; Olson, S. B. Growth of heterotrophic and algal extracellular products in oligotropic waters. Applied and Environmental Microbiology. 35(2): 383-391; 1978.

Meginnis, H. Influence of forest litter on surface run-off and soil erosion. American Soil Survey Association Bulletin. 16: 115-118; 1935.

Melack, J. M.; Stoddard, J. L.; Dawson, D. R. Acid precipitation and buffer capacity of lakes in the Sierra Nevada, California. In: Proceedings, international symposium on hydrometeorology; 1982 June 13-17; Denver, CO. Bethesda, MD: American Water Resources Association; 1982: 35-41.

Milne, C. M. Effect of a livestock wintering operation on a western mountain stream. Transactions of the American Society of Agricultural Engineers. 19: 749-752; 1976.

National Atmospheric Deposition Program (NADP). NADP quality assurance plan: deposition monitoring. Fort Collins, CO: Colorado State University, Natural Resource Ecology Laboratory; 1984. 39 p.

National Science Foundation. Long-term ecological measurements, report of a conference; 1977 March; Woodshole, MA. Washington, DC: National Science Foundation; 1977. 26 p.

National Science Foundation. Long-term ecological research—concept statement and measurement needs: summary of a workshop; 1979 June 25-27; Indianapolis, IN. Washington, DC: National Science Foundation; 1979. 27 p.

Norton, S. A.; Hess, C. T.; Blake, G. M.; Morrison, M. L.; Baron, J. Excess unsupported Pb-210 in remote Rocky Mountain lakes. Canadian Journal of Fisheries and Aquatic Sciences; [in press].

Parsons, D. J.; Graber, D. M. Integrated watershed research undertaken at Sequoia National Park. Park Science. 5(2): 22-24; 1985.

Pase, C. P.; Ingebo, P. A. Burned chaparral to grass: early effects on water and sediment yields from two granitic soil watersheds in Arizona. In: Proceedings, Arizona watershed symposium; 1965 September 22; Tempe, AZ. Phoenix, AZ: State Land Department, Watershed Management Division; 1965: 8-11.

Patrick, R.; Binetti, V. P.; Halterman, S. G. Acid lakes from natural and anthropogenic causes. Science. 211: 446-448; 1981.

Rantz, S. E. Measurements and computation of stream flow. Vol. 1, Measurement of stage and discharge; Vol. 2, Computation of discharge. Water Supply Paper 2175. Washington, DC: U.S. Department of the Interior, Geological Survey; 1982. 631 p.

Regelin, W. L.; Wallmo, O. C. Carbon black increases snowmelt and forage availability on deer winter range in Colorado. Research Note RM-296. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 4 p.

Rice, R. M. The hydrology of chaparral watersheds. In: Rosenthal, M., ed. Proceedings, symposium on living with the chaparral; 1973 March 30-31; Riverside, CA. San Francisco: Sierra Club; 1974: 27-33.

Rich, L. R. Erosion and sediment movement following a wildfire in a ponderosa pine forest in central Arizona. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1962. 12 p.

Rowe, P. B.; Countryman, C. M.; Storey, H. C. Hydrologic analysis used to determine effects of fire on peak discharge and erosion rates in southern California watersheds. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1954. 49 p.

Shaffer, P. W.; Galloway, J. N. Acid precipitation: the impact on two headwater streams in Shenandoah National Park, Virginia. In: Proceedings, international symposium on hydrometeorology; 1982 June 13-17; Denver, CO. Bethesda, MD: American Water Resources Association; 1982: 43-53.

Silsbee, D. G.; Larson, G. L. Water quality of streams in the Great Smoky Mountains National Park. Hydrobiologia. 89: 97-115; 1982.

Silverman, G.; Erman, D. C. Alpine lakes in Kings Canyon National Park, California: baseline conditions and possible effects of visitor use. Journal of Environmental Management. 8: 73-87; 1979.

Sinclair, J. D.; Hamilton, E. L. Streamflow reactions to a fire-damaged watershed. Proceedings, American Society of Civil Engineers. Preprint #629; 1955.

Skinner, Q. D.; Adams, J. C.; Rechard, P. A.; Beetle, A. A. Enumeration of selected bacteria populations in a high mountain watershed. Canadian Journal of Microbiology. 20: 1487-1492; 1974.

Skinner, Q. D.; Speck, J. E.; Smith, M. S.; Adams, J. C. Stream water quality as influenced by beaver within grazing systems in Wyoming. Journal of Range Management. 37(2): 142-146; 1984.

Slaughter, C. W. Snow albedo modification: a review of literature. USSSAC of Cold Regions Research and Engineering Laboratory; TR217; 1966. 25 p.

Staley, J. T.; Lehmicke, L. G.; Palmer, R. E.; Peet, R. W.; Wissmar, R. C. Impact of Mount St. Helens eruption on bacteriology of lakes in the blast zone. Applied and Environmental Microbiology. 43(3): 664-670; 1982.

Starnes, P. K.; Brown, R. A. Hydrocarbons in a wilderness lake. Marine Pollution Bulletin. 7(7): 131-132; 1976.

Stephenson, G. R.; Street, L. V. Bacterial variations in streams from a southwest Idaho rangeland watershed. Journal of Environmental Quality. 7: 150-157; 1978.

Stottlemeyer, R. Long-term trends in second-order stream chemistry, Isle Royale National Park. Bulletin of the Ecological Society of America. 65: 134; 1984.

Stuart, D. G.; Bissonette, G. K.; Goodrich, T. D.; Walter, W. G. Effects of multiple use on water quality in high mountain watersheds. Applied Microbiology. 22(6): 1048-1054; 1971.

Suk, T. J. Investigation of animal hosts for *Giardia* spp. in California's Sierra Nevada Mountains. Technical Report No. 11. Davis, CA: University of California, Cooperative Park Studies Unit; 1983. 21 p.

Swanson, E. L. A framework for the analysis of surface water quality in the Tonto National Forest. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977. 379 p.

Tunnicliff, B.; Brickler, S. K. Recreational water quality analyses of the Colorado River Corridor in Grand Canyon. Applied and Environmental Microbiology. 48(5): 909-917; 1984.

Turk, J. T.; Adams, D. B. Sensitivity of acidification of lakes in the Flat Tops Wilderness Area, Colorado. Water Resources Research. 19(2): 346-350; 1983.

Turner, R. M.; Karpiscak, M. M. Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. Geological Survey Professional Paper 1132. Washington, DC: U.S. Department of the Interior, Geological Survey; 1980. 125 p.

U.S. Environmental Protection Agency (USEPA). Working protocol for sampling, sample analysis, and QA/QC for the EPA long-term surface water monitoring program. Corvallis, OR: U.S. Environmental Protection Agency; 1985. 20 p.

U.S. Man and the Biosphere Program. Long-term ecological monitoring in biosphere reserves. Washington, DC: U.S. Man and the Biosphere Program; 1979. 31 p.

VanDonsal, D. J.; Geldreich, E. E. Relationships of Salmonellae to fecal coliforms in bottom sediments. Water Resources. 5: 1079; 1971.

Varness, K. J.; Pacha, R. E.; Lapen, R. F. Effects of dispersed recreational activities on the microbiological quality of forest surface water. Applied and Environmental Microbiology. 36(1): 95-104; 1978.

Walter, W. G.; Bottman, R. P. Microbiological and chemical studies of an open and closed watershed. Journal of Environmental Health. 30(2): 157-163; 1967.

Watling, R. J. The distribution of trace metals in the wilderness lakes. Water Science of America. 5(1): 1-13; 1979.

Welch, E. B.; Chamberlain, W. H.; Spyridakis, D. E. Chemical content of snow and effect of melting on Cascade mountain lakes. Northwest Science. 58(2): 85-93; 1984.

White, C. S.; Gosz, J. R.; Moore, D. I. Impact of a ski basin on a mountain watershed: bacteriological water quality. Water, Air and Soil Pollution. 10: 71-79; 1978.

Wiersma, G. B. Kinetic and exposure commitment analysis of lead behavior in a biosphere reserve. Report No. 15. London: University of London, Chelsea College, Monitoring and Assessment Research Center; 1979. 41 p.

Wiersma, G. B.; Brown, K. W. Recommended pollutant monitoring system for biosphere reserves. In: Proceedings, second conference on scientific research in the national parks; 1979 November 26-30; San Francisco, CA. Washington, DC: National Technical Information Service; 1979. 19 p.

Wiersma, G. B.; Brown, K. W.; Herrmann, R.; Taylor, C.; Pope, J. Great Smoky Mountains preliminary study for biosphere reserve pollutant monitoring. EPA 600/4079-072. Las Vegas, NV: U.S. Environmental Protection Agency; 1979. 47 p.

Wiersma, G. B.; Davidson, C. I.; Mizell, S. A.; Breckenridge, R. P.; Binda, R. E.; Hull, L. C.; Herrmann, R. Integrated monitoring in mixed forest biosphere reserves. In: Conservation science and society—contributions to the 1st International Biosphere Reserve Congress; Minsk, U.S.S.R. Paris: UNESCO; 1984: 395-403.

Williams, O. R. *Giardia* and the waterborne transmission of giardiasis: a general review. Report WSDG-TP-00003. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Watershed Systems Development Group; 1981. 25 p.

Willrich, T. L. Animal wastes and water quality. Ames, IA: Iowa State University, Department of Agriculture and Engineering; 1967. 16 p.

Wissmar, R. C.; Devol, A. H.; Staley, J. T.; Sedell, J. R. Biological responses of lakes in the Mount St. Helens blast zone. Science. 216: 178-181; 1982.

Wright, H. A.; Churchill, F. M.; Stevens, W. C. Effects of prescribed burning on sediment, water yield, and water quality from dozed juniper lands in central Texas. Journal of Range Management. 29: 294-298; 1976.

Wright, R. F. The impact of forest fire on the nutrient influxes to small lakes in northeastern Minnesota. Ecology. 57: 649-663; 1976.

AUTHORS

Raymond Herrmann
Chief, Applied Research Branch
Water Resources Division
National Park Service
Fort Collins, CO 80523

Owen R. Williams
Hydrologist, Water Rights Branch
Water Resources Division
National Park Service
Fort Collins, CO 80523

Section 3. State-of-Knowledge for Wilderness User Research

WILDERNESS USE AND USER CHARACTERISTICS: A STATE-OF-KNOWLEDGE REVIEW

Joseph W. Roggenbuck
Robert C. Lucas

ABSTRACT

Understanding wilderness use and users is essential for effective wilderness management, most of which is management of recreational use. Use and user research is less common now than a decade or two ago, although problems have multiplied and intensified as the wilderness system has expanded.

Similarities in use and especially users are more common than differences. Young adults, males, highly educated people, professional and technical occupations, moderately high incomes, predominantly local and regional visitors, low membership in conservation organizations, urban residents, considerable previous experience, and family groups are common characteristics. Use is distributed unevenly among areas, within areas, and over time. Parties typically are small, hiking, without outfitters, staying only a few days (or just for the day), and engage in multiple activities, with hiking, fishing, and photography most common.

The rate of increase in wilderness use has slowed, and use has declined in many areas. Use appears to be becoming more evenly distributed within many wildernesses with less pronounced peaks at certain times, stays are becoming shorter, parties are becoming smaller, there are more women visitors, and more visitors are visiting wildernesses not previously visited. The limited number of studies reporting data on these factors and noncomparability of measures and research methods require caution. Projections vary widely, although all project increasing use.

Research is needed to develop use measurement technology. Research needs to cover neglected areas and use outside the summer or summer and fall seasons, and be updated. Trends need emphasis, and longitudinal research is essential. A less cumbersome review and approval process is needed for research and monitoring. General population studies are needed as well as onsite visitor surveys. Visitors' knowledge of low impact use needs to be studied.

INTRODUCTION

Importance of the Topic

The importance of understanding wilderness use and user characteristics lies in the recognition that many of the important benefits of and threats to wilderness stem from wilderness use. The Wilderness Act (PL 88-577) specifies that the overriding value of wilderness is the protection of natural processes over a fairly large, undeveloped, and unoccupied area. However, the act recognizes that the protection of pristine areas is not an end itself. Instead, wilderness is "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness," and areas "shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness." The act goes on to specify in general terms what these user benefits are. Wilderness areas are to provide "outstanding opportunities for solitude or a primitive and unconfined type of recreation. . .and may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value."

The Wilderness Act specifies in general terms the bounds of appropriate wilderness uses and benefits. However, more precise definitions are needed when wilderness allocation decisions are made, wilderness policy is developed, and management plans are written. Wilderness allocations are made in an arena of competing demands among potential uses of an area's resources. Undeveloped lands might be classified as wilderness, but they might also be used to meet the Nation's needs for energy, timber, or roaded recreation experiences. When such decisions are made, resource planners, the President, and the Congress need information on use patterns and how wilderness users define "solitude and primitive and unconfined recreation." They need to know what social, psychological, and economic benefits are gained, or lost, when lands are set aside as wilderness. They need to know who receives these benefits, where, and how. What are the trends in wilderness use? Is the number of beneficiaries growing or declining? Are some wilderness values increasing in importance while others are declining? The wilderness user can help answer these important questions.

Once wildernesses have been established, use and user information is a prerequisite to the preparation of sound management plans. Hendee and others (1978) have suggested a goal-achievement framework for wilderness management planning that calls for the statement of goals, objectives, current situation and assumptions, and management mechanisms. Knowing the current situation and trends in such variables as amount of use, methods of travel, timing of use, travel patterns, length of stay, and group size greatly facilitates the specification of feasible objectives and selection of management mechanisms to achieve them. User opinions are an important source of input to the development of objectives. Such user data as place of residence can help resource planners and managers locate important clientele groups and effectively plan public involvement and education programs.

Accurate information on use and users is important for the management of wilderness for two reasons. First, wilderness management must for the most part be visitor management, because many other recreation management strategies are inappropriate. For example, site manipulation, site hardening, and facility development to prevent or mitigate impacts appear to conflict with the wilderness mandate for naturalness (Lucas 1982). Second, studies of wilderness users have consistently shown that freedom, spontaneity, and escape are highly sought values. Therefore, while visitor management is necessary, that management must be subtle, lighthanded, and unobtrusive (Lucas 1980, 1982; Wuerthner 1985). The wilderness manager must make every effort to permit users' freedom of choice—freedom at levels not necessarily found at less primitive outdoor recreation settings. This suggests that such authoritarian regulations as assigned departure times, entry points, travel routes, and campsites are generally inappropriate in wilderness. Instead, the manager might use access design and information, communication, and persuasion to modify behavior (Lucas 1981). Such management strategies require much more complete knowledge of use patterns, timing of use, and the attractions that draw visitors.

Information on use and users is also important in identifying causes and solutions of social and ecological impacts in wilderness. The relationship between amount of use and visitor-caused social and ecological impacts is not a linear one and depends on use characteristics as much or more than amount of use (LaPage 1967; Helgath 1975; Cole 1982). In explaining social impacts, and probably wildlife impacts as well, timing of use is often more important than amount of use; and visitor behavior, party size, and travel methods are more important than total use (Stankey 1973; Lee 1975).

Large increases in the number of wildernesses and the number of acres add to the importance of use and user research. From 55 areas, with 9 million acres, almost all in western States, all managed by one agency in 1964, the wilderness system has grown to 444 areas, with 89 million acres, in 44 States, managed by four agencies in 1984.

In summary, understanding use and user characteristics has value in itself, but it is also a key element in understanding many other dimensions of the wilderness social service system. By itself, knowledge of basic visitor characteristics permits an understanding of who, how many, when, where, and by what means people receive benefits from the wilderness. In addition, such visitor information can help wilderness policymakers, managers, and researchers understand the distribution of wilderness benefits among clientele groups, the behavior of users, and the causes and potential solutions to visitor-caused social and ecological impacts. When such visitor information is lacking for certain wildernesses or for large regions of the country, for certain seasons of the year, for certain user groups, or for key visitor characteristics, decisions must be based largely on intuition. Better knowledge of visitor characteristics increases the professionalism of wilderness management and can improve the quality of visitor experiences.

Scope of the Topic

Use and user characteristics relevant to wilderness allocation, planning, management, and research can be categorized roughly into five general areas: (1) basic demographic descriptions of visitors; (2) number and characteristics of visits; (3) motives for and benefits of use; (4) perceptions, attitudes, and behavior of visitors; and (5) trends and projections in use and user variables. In addition, knowledge of measurement methods is needed to obtain valid and reliable data on these use and user characteristics.

The scope of this paper is limited to research focusing on methods for collecting wilderness use and user data, basic demographic descriptions of wilderness visitors, characteristics of wilderness visits, trends and projections of use and users, and needs for additional use information. These basic user variables are closely related to motives for visiting wilderness, reasons for participating in various activities in wilderness, perceptions of conditions and experiences in wilderness, and wilderness attitudes and behavior. Motives, perceptions, attitudes, and behavior are often included in summaries of visitor surveys, but are omitted here. Stankey and Schreyer cover visitor attitudes and behaviors, and Driver, Haas, and Nash summarize wilderness benefits in separate papers in this volume. In addition, our summary is based almost entirely on published research reports, proceedings, journals, books, and selected theses and dissertations, with the addition of a few unpublished research reports. We have not reviewed the inhouse wilderness use and user records of resource management agencies except annual use reports. Finally, our literature review is largely limited to research completed on officially designated wilderness lands managed by the U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, National Park Service. Almost no published use and user research was found for U.S. Department of the Interior, Fish and Wildlife Service and Bureau of Land Management-managed lands, the other two Federal wilderness-managing agencies. Wilderness-related research conducted prior to 1964 when the Wilderness Act became law—most notably that in the Boundary Waters Canoe Area of Minnesota—was included, as was research on backcountry areas that later became or will likely soon become officially designated wilderness.

Our discussion of measurement methods describes the peculiarities of collecting visitor data in wilderness settings and identifies common problems that need to be addressed. Demographic characteristics of wilderness users included in our analysis are age, sex, education, occupation, income, place of residence, previous wilderness experience, group type, and club membership. Wilderness visit characteristics include amount of use, spatial distribution of use, time of use, party size, length of stay, method of travel, use of outfitter services, and visitor activities. Trend analyses and projections are reported for those few use and user variables for which sufficient longitudinal data are available.

GENERAL EVOLUTION OF RESEARCH

Focus

Use and User Characteristics Research.—Studies of wilderness use and user characteristics began in the late 1950's (Stone and Taves 1957; Taves and others 1960) and were emphasized in the 1960's (Bultena and Taves 1961; ORRRC 1962; Merriam 1963; Lucas 1964a; Merriam and others 1965; Burch 1966; Burch and Wenger 1967; Merriam and Ammons 1967; Hendee and others 1968). Active research continued to at least the mid-1970's (Jubenville 1971; Lime 1972; Murray 1974; Kennedy and Brown 1976; Stankey and others 1976; Bratton and others 1977; Nielsen and Shelby 1977; Echelberger and Moeller 1977).

In the early period, studies of use and user characteristics were a response to a perceived need to know who the users were, how many of them there were, and how they used wilderness. At the beginning of this period, there was a near vacuum of basic information about wilderness recreation, and great uncertainty about both its magnitude and characteristics.

Use Measurement Research.—A related topic, recreational use measurement technology, also received considerable research attention early (Lucas 1963; Wenger 1964; Wenger and Gregersen 1964; Lucas and Schweitzer 1965; Lucas and others 1971; James and Schreuder 1971, 1972; Elsner 1972; Lime and Lorence 1974; Lucas 1975; DeLand 1976; Marnell 1977; Ciali and others 1978; Gasvoda 1978; Plumley and others 1978) but less attention more recently (Kraushaar and others 1979; Leonard and others 1980; Leatherberry and Lime 1981; Lucas and Kovalicky 1981; Scotter 1981; Saunders 1982; Lucas 1983; Huppuch and Pellerin 1984; Petersen 1985).

Several of the early use measurement studies, particularly those in which James participated, sought to develop overall systems for estimating use of an entire wilderness, usually based on integrating trail registers and traffic counters. James headed a Forest Service recreation research unit in North Carolina with a national mission of developing recreation use measurement methods for all types of recreation areas and wilderness. Many other studies, and almost all of the more recent ones, had much more limited objectives dealing with components of the use measurement process, such as trail register registration rates or use counting with electronic or photographic techniques.

Decline in Use/User Research.—In the 1960's there seemed to be a consensus that professional wilderness management required reasonably accurate recreational use measurement, that guesses and rough approximations were not adequate to plan for fieldwork and public contact, to assess trends, or for research on impacts and visitor perceptions of crowding. However, coordinated research to provide wilderness managers with this needed technology largely ended early in the 1970's when the Forest Service's recreation use measurement research unit in North Carolina was discontinued, probably just short of development of a satisfactory cost-effective system for wilderness, for reasons that are not clear to us.

Most of the early surveys of wilderness use and users were fairly comprehensive, covering visit characteristics such as activities, method of travel, and length of stay; group characteristics such as party size and type of social group; and individual socioeconomic characteristics including residence, age, sex, education, occupation, and income. Often attitudes and preferences were also studied and sometimes experience. The surveys were rarely "mere description" or simple censuses. They usually focused on management issues in the study area, and generally analyzed differences among various types of visitors, classified on a variety of bases, such as method of travel, personal wilderness orientation, and experience.

Comprehensive wilderness visitor surveys became scarce after the middle 1970's and nearly disappeared in the 1980's. Only a few use and user studies were published after 1977 (Leonard and others 1978; Plumley and others 1978; Roggenbuck and others 1979; Lucas 1980, 1985b), and these were based on data collected earlier. A survey of residents of southwest and south-central Alaska covered much wilderness-type recreation (Clark and others 1982). There also were basic visitor surveys of river recreationists (Lime and others 1981), including some rivers in wilderness settings.

This decline in research attention has many possible causes. Probably the major cause is a feeling, right or wrong, that the topic has been adequately dealt with, and that, in a sense, the answers are known. Furthermore, tighter budgets and research cutbacks have forced more concentration of research on the highest priority problems, and we sense that most researchers have considered use and user studies to be lower priority. Topics more closely related to visitor experiences and behavior and their explanation and management have been assigned higher priority. Researchers also have increasingly recognized the strengths of experimental approaches contrasted to survey research.

We do not disagree entirely with their positions, but we believe that all the answers to important questions are not known. First, trends in use and user characteristics are almost unstudied, and without further comparable studies our knowledge of trends will remain extremely skimpy. Second, wilderness use/user research has been very uneven in its coverage of the wilderness system and its use. As figure 1 shows, studies have been concentrated in the Northern Rockies, the Pacific Northwest, and northern Minnesota. Relatively few studies have been conducted in the East and California. The Desert Southwest and the South are little studied. River runners have been studied more widely (Lime and others 1981), including most of these regions, but wilderness users have not been studied nearly as evenly. (Differences in the difficulty of sampling the more widely dispersed wilderness visitors compared to river floaters probably contribute to this contrast. Rivers typically have fewer access points, while wildernesses commonly have a great many trailheads, over 70 in both the Boundary Waters Canoe Area and the Bob Marshall Wilderness complex, for example.) This has hampered analysis of patterns of variations among regions and agencies. Finally, we think many wilderness managers still feel a need for good profiles of their users.

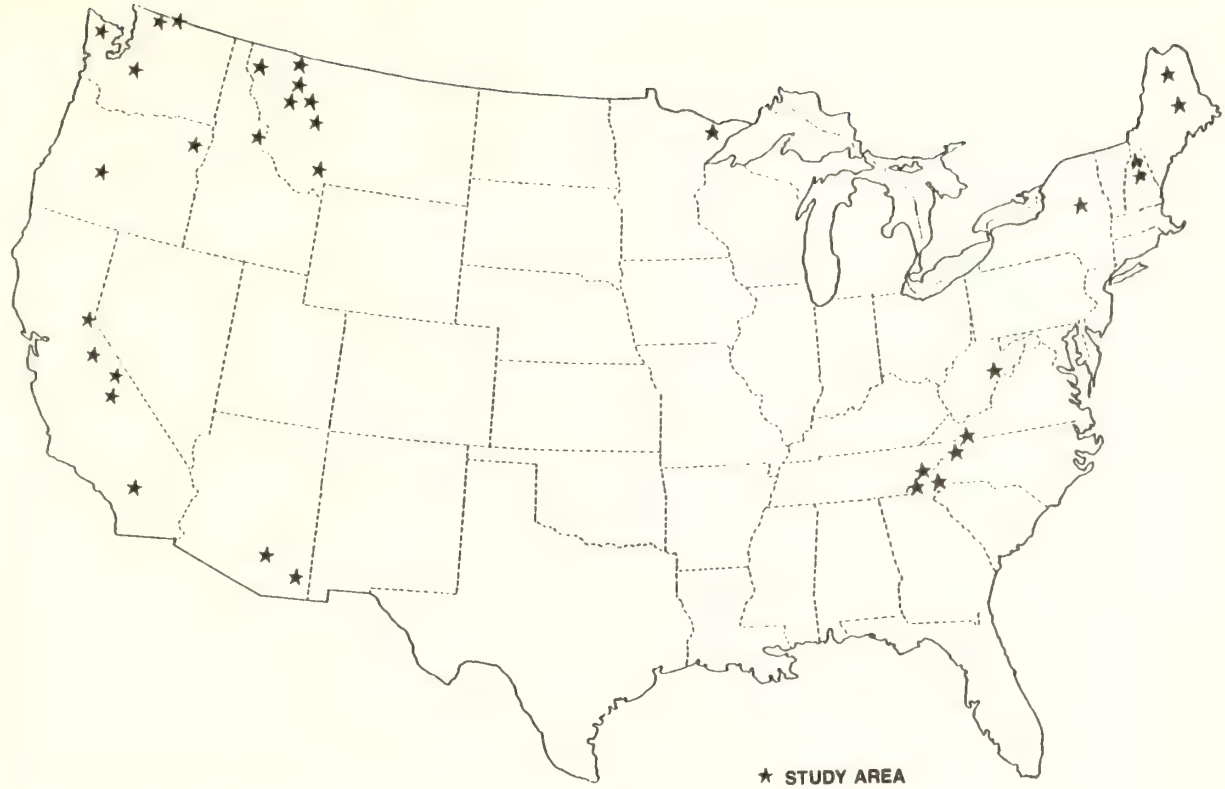


Figure 1.—Map of areas studied in published use and user research.

The shift in wilderness research emphasis in the 1970's away from basic descriptions of use and users and toward an understanding of the individual and social meanings and benefits of wilderness recreation resulted in part from an expanded and more comprehensive conceptualization of outdoor recreation. Prior to the 1970's, recreation was viewed primarily as participation in activities (Driver and Tocher 1970). Thus, fishing was recreation, swimming was recreation, and so on. There are many different types of fishing, for example, in highly varied settings that have little in common in terms of resources and management. Activity definitions of recreation may have hampered efforts to answer such important policy questions as "Why is the recreationist participating in the activity?" "What satisfactions or rewards are received from the activity?" and "How can the quality of the experience be enhanced?" (Driver and Tocher 1970, p. 10). To try to answer these questions, many recreation planners and researchers began to focus on the recreation experience: the sum of a participant's mental, spiritual, physiological, and other responses to a recreational engagement. Researchers expanded efforts to learn what outcomes wilderness users were seeking, their degree of satisfaction with the wilderness experience, perceptions of crowding within the wilderness setting, perceptions of conflict, and preferences for setting attributes that enhance wilderness experiences, stressing psychological research methods. In many of these studies, researchers also obtained information on socio-demographic characteristics of the wilderness visitors, but these data were generally collected only in an effort to better understand the dimensions of the wilderness experience or with the anticipation that such basic data could help planners and managers identify and meet the needs of varying clientele.

Another emphasis in wilderness user research focuses on visitor knowledge and actual behavior. This research thrust likely has several explanations. Wilderness managers have become increasingly concerned about user impacts on the land and others' experiences. At the same time, managers have become aware of the need to foster visitor freedom as a value of wilderness. Given this, managers have increasingly turned to education in an effort to lessen impacts (Washburne and Cole 1983).

Interest in behavior stems in part from the debate among social scientists in general (Deutscher 1973) and recreation researchers in particular (Heberlein 1973) on whether people behave as their knowledge, beliefs, or attitudes would suggest. When behavior is the issue of interest, as it often is in studies of conflict, crowding, and impact in wilderness, then behavior becomes the most relevant focus. Studies of both visitor knowledge and behavior have typically included some socio-demographic variables in an effort to explain study findings. Level of experience, for example, appears to influence users' tendency to respond to suggestions for use dispersal within an area (Lime and Lucas 1977; Roggenbuck and Berrier 1982).

Finally, in recent years there has been renewed research interest in visitor impacts on soil and vegetation in wilderness. This research has often included measures of amount, time, and type of use in an effort to better understand the relationships between use and impacts (Cole 1982, 1983; Marion and Merriam 1985).

Projections.—Research on wilderness recreational use projections has not been common (ORRRC 1962; Jungst and Countryman 1982; Hof and Kaiser 1983a, 1983b; Oliveira and others 1983). Unlike the basic surveys of use and users, all but one of the projection studies have been done recently. Projection research is hampered by the scarcity of recent visitor surveys to provide data on which to base projections.

Trend Research.—Trend analyses of use and users also have been scarce (Lucas 1967; Cieslinski 1980; Petersen 1981; van Wagtendonk 1981; Corti and others 1982; Lucas 1985a, 1985b; Burde and Curran 1986). As was true for use projections, all but one of the trend studies have been done in the last few years.

Development of Research Methods

Data Collection Problems.—Gathering data for studies of wilderness recreational use and users is difficult and costly if adequate samples are to be obtained. A number of characteristics of wilderness recreational use contribute to the difficulty.

Wilderness use is relatively light and widely dispersed. Typical wildernesses have many access points, and visitors spread out widely from the access points. Furthermore, use usually is highly variable from time to time, responding to weather, weekend leisure or weekday obligations, holidays, hunting and fishing seasons, and so on. As a result, the number of people present at any place at one time is usually low, and often there may be no one to contact or observe. Much fieldwork can produce little data, and costs are often high.

Another factor impeding efficient sampling is the lack of adequate basic use data to plan when and where to do fieldwork. Planning efficient access point sampling, for example, depends on reasonably good data on the distribution of use. The advantages of stratification or of sampling with probabilities proportional to size are reduced or lost if basic use data prove to be seriously inaccurate, as is sometimes the case.

Ethics sometimes limit certain kinds of data collection as well. Because of the particular character of the wilderness experience, disturbance of visitors during their experience may be undesirable. Many researchers have avoided contacting visitors within the wilderness, choosing rather to make contacts at access points before, or, more often, after the wilderness visit. Ethics also require care in use of observation techniques. Observation that might be fairly easy and unobjectionable in developed campgrounds where many people are normally present is a different matter for isolated campers in a wilderness who may believe they are the only people for miles.

Unobtrusive observation can take on some characteristics of spying, and can raise troubling questions of invasion of privacy and consent that researchers have had to face and deal with sensitively. This is an issue for both personal and photographic observation. More open, direct observation can also cause concern in some settings, particularly at campsites. Research has shown the high importance many wilderness visitors attach to campsite solitude (Stankey 1973). Researchers thinking of deliberately approaching visitors or camping near them for observational purposes have had to consider the importance of campsite solitude to some if not most of the visitors, as well as the effect their presence may have on the behavior being observed. These concerns add to the problems of efficiently gathering data on wilderness use and users.

Several studies have coped with these problems and used observation with care. Heberlein and Dunwiddie (1979) unobtrusively observed campsite selection and party characteristics at a popular lake in the Bridger Wilderness in Wyoming. Modified movie cameras provide another type of observation. Cameras either operate in a time-lapse fashion (Marnell 1977) or are triggered to expose one or a few frames by a trail traffic counter (Leatherberry and Lime 1981; Petersen 1985). Cameras have been used on trails and rivers, which are public places where visitors are passing by, not at campsites where privacy is more critical.

Analysis of agency wilderness use data is hampered by noncomparable units of measure used by the four Federal wilderness-managing agencies—National Park Service, Fish and Wildlife Service, Bureau of Land Management, and Forest Service. This has been a problem, for example, in trend analysis (Petersen 1981) and comparison of use intensity (Hendee and others 1978, chapter 13; Washburne and Cole 1983). Long-term trend analysis is also hampered by a shift in units of measure by the Forest Service in 1965 from visits and man-days to recreational visitor-days. No conversion factors exist.

Sampling Methods.—Early in the 1960-to-present period, survey research was almost the only approach used in wilderness use and user studies, and it has continued to be the most common technique. Survey methods have improved substantially over the years.

Sampling techniques have improved. Early in the 1960's, the existence of a length-of-stay bias in onsite visitor sampling was recognized (Lucas 1963) and ways of avoiding or correcting for it were developed (Lucas and Schweitzer 1965). Probability samples replaced informal convenience samples that had no definable relationship to the population of interest. For example, some very early surveys depended on interviews with whomever the researcher met while traveling through the wilderness. This resulted in small samples, length-of-stay bias (the probability of a visitor being contacted was a function of the length of time he was in the area), and geographically unrepresentative samples.

Most visitor survey field techniques produce cluster samples rather than simple random samples (Lucas and Oltman 1971). For example, fieldworkers typically are stationed at a particular access point for some limited time—such as part of a day. The resulting sample is a cluster of visitors for that time and place, and probably the sample is more homogeneous than an unclustered simple random sample of the same size. Early studies failed to recognize this property. Therefore, they were not designed to be as efficient as possible and improper statistical procedures were used. This weakness has been corrected in some studies, but misuse is still common.

Sources of visitor samples became more diverse, which often resulted in better samples. Personal contacts in the field were supplemented by use permits, special trail registers, outfitter guest lists, and so on. Approaches that did not involve direct contact in the field usually depended on mail questionnaires. This technique was used more often in later studies, even those with initial personal contact, in contrast to more use of personal interviews in earlier studies. Mail questionnaire techniques were refined and achieved very high rates of return, usually in the 80 percent range, occasionally higher. Most mail questionnaires probably imposed less on visitors at access points than the more time-consuming personal interviews because of the desire by many visitors to either start their trip or head for home.

Visitors might have more time available for interviews inside the wilderness, especially at campsites. However, not only the ethical concerns raised before but also the sampling problems discussed make this an unsatisfactory approach to most research questions (although for studies of visitor perception of onsite conditions it is an appropriate method). In this situation, the mail questionnaire worked well and avoided problems with ethics and sampling design, and therefore it became a common approach. In contrast, telephone survey techniques (Field 1973) have rarely been applied to wilderness research.

Sampling Frames.—The unit of analyses in visitor use and user studies has been either the visitor group (often represented by the party leader), or individual members of the group, usually above some age such as 12 or 15. Party leader-based studies were probably more common in early research. Neither unit of analysis is necessarily superior; the appropriate unit depends on the study objectives. Most wilderness visitors are in groups; typically less than 10 percent of all parties consist of one person. Much group decision making and behavior results from intragroup social dynamics. But if describing the characteristics of wilderness visitors is an objective, studying only party leaders will produce seriously misleading results (Jubenville 1971).

Most wilderness use/user studies have been based on visitors to a particular wilderness. Very few have been household surveys that include nonvisitors—including former visitors and potential visitors. One exception is Young's (1983) survey of the general public in Illinois. Again, neither is right nor wrong except in relation to study objectives (Shechter 1977).

RESEARCH RESULTS

This section presents a comprehensive review of research on wilderness use patterns, user characteristics, use measurement strategies, trend analyses, and projections. Data typically are presented in tabular form broken down by area of study, year of study, and season of data collection. This permits analyses of differences in wilderness use and user characteristics by region of the country, season of the year, and across time. It permits the review of patterns among use and user variables, and also illustrates gaps in the data. Because the summary tables represent studies by many authors working at different times, under varying circumstances, with differing objectives, and using different data classifications, the precision of the information provided varies a great deal. For this reason, we have looked for and discussed replicated findings and gross patterns. Finally, we have often compared wilderness user characteristics to general characteristics of the United States population. This permits identification of the segments of the general population that are receiving the benefits of wilderness and those that are underrepresented.

Use Patterns

Amount of Use.—Of the four Federal agencies with lands included in the National Wilderness Preservation System, only the Forest Service separates wilderness from other dispersed recreation areas in its reports of recreational use. National Forest wilderness and primitive area use was 10.2 million standard 12-hour visitor-days in 1984. Use figures become more meaningful when reported on a per-acre basis. Visitor-days of recreation use of National Forest wilderness and primitive areas was 0.31 visitor-day per acre in 1984. Additions to the wilderness system, particularly large, lightly used areas in Alaska (which averaged only 0.05 recreation visitor-day per acre in 1984) have lowered the average concentration of use for the overall system.

The National Park Service records backcountry overnight stays, many of which occur in wilderness or similar undesignated parts of Parks. In 1984, overnight backcountry stays in 47 National Parks with designated or potential wilderness totaled 0.9 million. This is probably equivalent to about 1.8 million 12-hour recreation visitor-days. Day-use data are generally unavailable for National Park backcountry, in contrast to National Forest wilderness, but day-use is undoubtedly substantial for many of these four dozen parks. In Yosemite National Park, for example, visitor-days of day-use were estimated at roughly half or slightly less of the total visitor-days accounted for by overnight visitors (Hendee and others 1978). If this were the case for all parks, then the wilderness and backcountry parks accounted for about 2.7 million visitor-days of wilderness recreational uses in 1984. This would average less than 0.08 visitor-day per acre, with large, lightly used Alaskan areas pulling the average down. Wrangell-St. Elias National Park includes 8.7 million acres of wilderness and reported 1,931 overnight backcountry stays in 1984, about 0.0004 12-hour visitor-days per acre. Hendee and others (1978) estimated that use of all National Park backcountry and wilderness was 3 to 5 million visitor-days in 1975, although reported use has declined since then.

Time of Use.—Amount of use is distributed very unevenly across seasons of the year and days of the week in virtually all wilderness areas studied. Summer is the big season of use almost everywhere, generally accounting for 60 percent or more of all use (table 1). Even in areas such as the Bob Marshall and the Great Bear Wildernesses, famous for their fall big game hunting, summer use still substantially outnumbers fall use (Lucas 1980). Also, recent studies of three western wilderness areas suggest that the concentration of use during the summer season may be increasing (Lucas 1985b).

There are, however, brief peaks of off-season use in some wilderness areas. Popular hunting areas such as the Great Bear Wilderness have heavy use during the first week or two of the hunting season. Some areas in the South, Southeast, and low elevations in the Southwest and

Table 1.—Time of wilderness use, weekday or weekend and season, by area

Wilderness area (State)	Year	Season	Percent of total visitors: Time of week: Weekday	Weekend[2]	Season of year[1]: Summer	Fall	Winter	Spring	Source
Bob Marshall (MT)	1970	Summer/Fall	34	66	60	40			Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	27	73	82	18			Lucas 1980
Great Bear (MT)	1970	Summer/Fall	24	76	55	50			Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	43	57	86	14			Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	27	73	84	7			Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	42	58	71	28			Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	39	61	68	32			Lucas 1980
Desolation (CA)[3]	1972	All year	46	54	76	20	4		Lucas 1980
Great Gulf (NH)[4]	1976								
—day-use			66	34					Leonard and others 1978
—overnight use			68	32					Leonard and others 1978
Linville Gorge (NC)[4]	1978	Summer/Fall	47	[5]31(22)	66	34			Roggenbuck and others 1979
Shining Rock (NC)[4]	1978	Summer/Fall	40	[5]29(31)	56	44			Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)[4]	1978	Summer/Fall	44	[5]52 (4)	57	43			Roggenbuck and others 1979
Chiricahua Mountains (Cave Creek Canyon) (AZ)	1978-79	All year			32	19	11	39	Shaw and Richards 1979
Great Smoky Mountains NP backcountry (NC & TN)	1979	Winter	33	77					Hammitt and Hughes 1984
	1979	Summer	52	48					Hammitt and Hughes 1984
Bob Marshall Wilderness complex (MT)[6]	1982	Summer/Fall	42	58	77	24			Lucas 1985b

[1] Season of year percentages are percentages of total use of those seasons studied.
[2] Unless otherwise noted, weekend use equals wilderness use that began on Friday, Saturday, or Sunday.
[3] Figures for Desolation Wilderness represent percentages of total user groups.
[4] Weekend use is use that occurs on Saturday and Sunday.
[5] Figure in parentheses represents percentage of total visitors whose visits covered both weekends and weekdays.
[6] The Bob Marshall complex indicates the Bob Marshall, Great Bear, and Scapegoat Wildernesses.

southern California have spring peaks in use. For example, the Chiricahua Mountains of southeastern Arizona receive heaviest use in the spring. In the East and Southeast, fall color attracts many visitors during October. Finally, while winter use is generally light, it is much more common than a decade ago, and is growing.

In his studies of nine western wilderness areas, Lucas (1980) found that from two-thirds to three-fourths of all visitors entered the wilderness on Fridays, Saturdays, Sundays, and during the two summer holidays (Independence Day and Labor Day) (table 2). Hendee and others (1978) reported severe weekend peaking of use on such smaller, more accessible wildernesses as the San Gorgonio and San Jacinto in California, and they hypothesized that weekend peaking was probably common in eastern wildernesses. Recent research, however, suggests that concentrations of use on weekends are not as high as expected in the East. In the Great Gulf Wilderness, three National Forest wildernesses in the Southeast, and the Great Smoky Mountains National Park in the summer, weekday use accounted for 40 to 68 percent of all use. The eastern studies have been completed more recently, and they may reflect changes in use distribution across time. Lucas (1985b) noted that weekend peaking of use was less pronounced in the Bob Marshall Wilderness complex in 1982 than it was in 1970. In contrast, Hammitt and Hughes (1984) noted that 1979 winter backcountry use in the Great Smoky Mountains was highly concentrated on weekends. About 77 percent of all winter use there occurred on Saturday or Sunday.

Distribution of Use Among Areas.—The geographical distribution of wilderness use across areas is extremely variable (table 2). Some areas are heavily used, while others are virtually untouched. Heavily used areas tend to be located near population centers, often in the Southern Appalachians, New England, Minnesota, and California. Compared to the average visitor-day use per acre of National Forest wilderness in 1984 of 0.31, use of North Carolina wildernesses averaged 5.24; Indiana, 2.36; Tennessee, 2.29; Georgia, 2.07; Minnesota, 1.16; New Hampshire, 1.07; Alabama, 0.96; California, 0.73; and West Virginia, 0.79. At the same time National Forest wildernesses in the States of Alaska and Florida averaged 0.05, and Idaho, Montana, Nevada, and Wyoming averaged less than 0.25 visitor-day/acre.

Table 2.—Amount and intensity of recreational use of selected National Forest wildernesses, 1984[1]

Area	Total recreation visitor-days (RVD's)	RVD's per acre
Boundary Waters Canoe Area (MN)	1,252,700	1.16
John Muir (CA)	449,900	.77
Frank Church-River of No Return (ID)	368,800	.16
Absaroka-Beartooth (MT)	332,300	.36
Indian Peaks (CO)	332,000	4.72
Alpine Lakes (WA)	287,800	.78
Weminuche (CO)	263,300	.57
Selway-Bitterroot (ID-MT)	224,400	.17
Desolation (CA)	220,000	3.47
Bridger (WY)	218,100	.51
Emigrant (CA)	216,900	1.93
San Gorgonio (CA)	191,700	3.38
Rockpile Mountain (MO)	900	.22
Withington (NM)	900	.05
Bristol Cliffs (VT)	800	.21
Little Wambaw Swamp (SC)	800	.16
Wambaw Swamp (SC)	700	.14
Warren Island (AK)	500	.04
Muralla Island (AK)	500	.10
Endicott River (AK)	500	.01
Coronation Island (AK)	400	.02
Hell Hole Bay (SC)	100	.05
Shining Rock (NC)	123,700	6.70
Linville Gorge (NC)	72,900	6.64
Dome (NM)	29,800	5.73
Great Gulf (NH)	24,900	4.48
Never Summer (CO)	59,500	4.34
Gee Creek (TN)	9,100	3.65
Mt. Baldy (AZ)	25,700	3.63
Mokolumne (CA)	18,700	.18
Bob Marshall (MT)	148,300	.15
Bell Mountain (MO)	1,000	.11
Washakie (WY)	60,900	.09
Galiuro (AZ)	7,000	.09
Lee Metcalf (MT)	19,700	.08
Welcome Creek (MT)	1,900	.07
Kalmiopsis (OR)	12,000	.07
Hells Canyon (ID-OR)	13,100	.06
South San Juan (CO)	5,900	.05
Bradwell Bay (FL)	1,300	.05
Aldo Leopold (NM)	10,100	.05
Misty Fiords (AK)	39,300	.02
Total for all National Forest wilderness	10,209,300	0.31

[1] Based on the fiscal year from October 1, 1983, through September 30, 1984.

Eleven National Forest wildernesses reported over 200,000 visitor-days of use in 1984, and one, the Boundary Waters Canoe Area Wilderness (BWCAW), reported 1,252,700 visitor-days. These top 11 accounted for 41 percent of the total recreation use reported for the 165 areas designated at the beginning of 1984. Hell Hole Bay Wilderness in South Carolina had only 100 visitor-days of use, and nine other areas reported less than 1,000. Half of these lightly used areas were in the East, half in the West (most in Alaska). Low use in the eastern areas might be explained by their recent inclusion in the National Wilderness System or lack of scenic attractions.

The estimates of visitor-day use per acre suggest equally large variation in concentration of use across areas. Six National Forest wildernesses (Linville Gorge and Shining Rock in North Carolina, Indian Peaks and Never Summer in Colorado, Dome in New Mexico, and Great Gulf in New Hampshire) had visitor-day use in excess of 4.00 per acre. At the same time, five areas (South San Juan in Colorado, Aldo Leopold in New Mexico, Hell Hole Bay in South Carolina, the North Absaroka in Wyoming, and Bradwell Bay in Florida) had 0.05 visitor-day per acre or less, as did nine National Forest wildernesses in Alaska.

Limited National Park Service data also indicate uneven distribution of use across areas. Yosemite, Sequoia, Kings Canyon, and Grand Canyon National Parks all reported close to or over 100,000 backcountry overnight stays in 1984. During the same year, several National Parks with wilderness-type lands, including Badlands, Big Thicket, Cape Krusenstern, Craters of the Moon, Death Valley, Kobuk Valley, Katmai, and Lava Beds, reported less than 1,000 overnight stays. Some reported no use.

Intra-Wilderness Use Distribution.—Use varies as much within as between wilderness areas. In studies of entry point use, one entry point sometimes accounts for over half of all use. Lucas (1964a) found that 52 percent of all paddling canoeists in the BWCA originated from one access point. In 1974, seven of the BWCA's 70 entry points accounted for 70 percent of all use (table 3). In 1984, use was reported for 88 entries; the top 10 accounted for 51 percent of all use. In Lucas' study of nine western areas (Lucas 1980), just three trailheads accounted for half or more of all use in every area except the Selway-Bitterroot. Generally, one-fourth of the access points had 80 percent or more of all use. In each of the nine areas, some of the trailheads were not used by any of the sampled individuals. Disproportionately high use of only a few entry points seems less pronounced in the East, but use is even more concentrated at trailheads in Yosemite National Park (table 3).

Lucas (1985b) has reported some dispersal of use to more lightly used trailheads recently in the Bob Marshall, Great Bear, and Scapegoat Wildernesses. In 1970, between 7 and 25 percent of the entry points to each of these three areas accounted for 80 percent of all use. In 1982, this amount of use entered at 33 to 45 percent of the areas' trailheads.

Use of trail segments inside wildernesses is also extremely variable. For example, while the Spanish Peaks Primitive Area had one of the most even trail use distributions among areas that Lucas (1980) studied, about 50 percent of all its visitor-miles of travel occurred on 10 percent of its trail miles. Thirty percent of its trail miles had 70 percent of all visitor use. Similarly, on some lakes in the Boundary Waters Canoe Area, contacts with other parties of canoeists are more than 40 times as numerous as on other lakes (Lime 1975). Variations in trail use concentration appear to be little related to either area size or intensity of use, but instead seem to be related to trailhead location relative to population centers, ease of road access to trailheads, location of attractions within the area, extent of trail development and trail configuration

Table 3.—Concentration of total wilderness use among high use entry points by area

Wilderness area (State)	Year	Season	High use entry points		Source
			Percent of total entry points	Percent of total use	
Bob Marshall (MT)	1970	Summer/Fall	25	83	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	50	81	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	9	85	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	25	81	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	38	82	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	25	85	Lucas 1980
Selway-Bitterroot (MT & ID)	1970	Summer/Fall	26	82	Lucas 1980
Desolation (CA)	1970	Summer/Fall	29	83	Lucas 1980
Boundary Waters Canoe Area (MN)	1974		10	[1]70	Hendee and others 1978
Indian Peaks (CO)	1976	Summer	44	78	Brown and others 1977
Yosemite NP backcountry (CA)	1973	All year	4	68	van Wagtendonk 1981
	1979	All year	4	60	van Wagtendonk 1981
Maroon Bells-Snowmass (CO)	1978	Summer	23	80	Haas and others 1982
Linville Gorge (NC)	1978	Summer/Fall	21	55	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	38	85	Roggenbuck and others 1979
Great Smoky Mountains NP backcountry (NC & TN)	1979	Winter	29	[1]88	Hughes 1985
	1979	Summer	26	[1]77	Hughes 1985
Bob Marshall (MT)	1982	Summer/Fall	37	79	Lucas 1985b
Great Bear (MT)	1982	Summer/Fall	33	81	Lucas 1985b
Scapegoat (MT)	1982	Summer/Fall	45	80	Lucas 1985b

[1] Percent of total user groups.

within the area, and distance from trailhead to the wilderness periphery.

Distribution and amount of use of campsites within wildernesses also vary a great deal, with much use concentrated at popular attractions. Large, reasonably accessible lakes are an important attraction for campers almost everywhere. In an inventory of campsites in the Spanish Peaks Primitive Area, Brown and Schomaker (1974) found that half of all campsites were within 50 feet of a lake or stream, two-thirds were within 100 feet, and 85 percent were within 200 feet. Depending on such variables as accessibility, proximity to water, and presence of a view, use of individual campsites is uneven. For example, 16 percent of the campsites in the Desolation Wilderness accounted for over half of all use; the least-used half had only 18 percent of all use (Hendee and others 1978). Many campsites in the 1982 study of the Bob Marshall Wilderness complex were estimated to receive less than 30 nights of use during the use season, but a number had over 120 nights of use (or almost constant use). Finally, Hughes (1985) reported more concentrated campsite and shelter use in the Great Smoky Mountains National Park backcountry in winter than in summer. Approximately 62 percent of winter campers used shelters, compared to 40 percent in summer. In winter, two of the park's 18 shelters accounted for 33 percent of all shelter use, and eight shelters had 73 percent of all use. In contrast, two shelters had 18 percent of all shelter use in summer, and seven had 53 percent.

Party Size.—Most wilderness parties (groups of individuals traveling together) are small, and appear to be getting smaller. For all areas studied, at least half of all groups were two- to four-person groups (table 4). In some areas groups of this size accounted for 75 percent of all parties. Two-person groups are the most common. Lone individuals are scarce in wilderness, as are groups with over 10 people. For most National Forest areas studied, the percentage of one-person groups was only about 5 to 10 percent. Interestingly, lone individuals using National Park backcountry were more numerous, generally equaling between 10 and 15 percent of all user groups. Parties of more than 10 people usually numbered about 5 percent of all groups everywhere. Two notable exceptions were Montana's Scapegoat Wilderness in 1970, with 14 percent, and California's San Gorgonio Wilderness in 1972, with 25 percent. Average size of user groups was somewhat smaller in National Park wilderness and backcountry than in National Forest wilderness. While parties averaged four to five people on National Forests, averages were typically two to three individuals on National Park lands.

Large parties were more likely to be horse users or river rafters than hikers, and campers rather than day-users, in Lucas' (1985b) study of the Bob Marshall Wilderness complex. Hunters and nonhunters had similar proportions of large parties. Finally, Lucas (1985a) suggested that group size may be getting smaller. In 1970, groups in the Great Bear and Scapegoat Wildernesses averaged 5.2 and 5.6 individuals, respectively. By 1982, these numbers had declined to 3.8 and 4.4. Many areas have placed restrictions on group size in an effort to reduce ecological and social impacts in wilderness. These limits, however, have typically been larger than most groups, so this regulation has likely had little effect on average group sizes. Users themselves, particularly the leaders of organized groups, have apparently become aware of the disproportionately high impacts of large groups, and have reduced their group sizes.

Table 4.—Party size of wilderness visits by area

Wilderness area (State)	Year	Season	Average size	Percent of total parties of indicated size[1]				Source
				1	2-4	5-10	11+	
Boundary Waters Canoe Area (MN)[2]	1961	Summer	5.0					Lucas 1964a
Bob Marshall (MT)	1970	Summer/Fall	4.7	6	50	42	2	Lucas 1980
	1982	Summer/Fall	4.7	6	61	25	8	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	4.0	5	69	17	4	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	5.2	0	66	27	7	Lucas 1980
	1982	Summer/Fall	3.8	5	72	22	1	Lucas 1985b
Scapegoat (MT)	1970	Summer/Fall	5.6	6	60	20	14	Lucas 1980
	1982	Summer/Fall	4.4	11	60	23	6	Lucas 1985b
Mission Mountains (MT)	1970	Summer/Fall	4.5	5	56	31	5	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	4.8	8	56	27	6	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	4.5	5	65	22	6	Lucas 1980
Desolation (CA)	1972	All year	3.8	10	66	18	4	Lucas 1980
John Muir (CA)	1972			9	72	12	7	Hendee and others 1978
San Gorgonio (CA)	1972			7	53	15	25	Hendee and others 1978
Yosemite NP backcountry (CA)	1972			14	71	12	3	Hendee and others 1978
Sequoia-Kings Canyon NP (CA)	1972			13	75	7	5	Hendee and others 1978
North Cascades NP (WA)	1974			13	63	18	6	Hendee and others 1978
Olympic NP (WA)	1974			14	72	9	5	Hendee and others 1978
Mount Rainier (WA)	1974			13	71	14	2	Hendee and others 1978
Yosemite NP backcountry (CA)	1972	All year	3.2					van Wagtendonk 1981
	1973	All year	3.1					van Wagtendonk 1981
	1974	All year	3.0					van Wagtendonk 1981
	1975	All year	3.0					van Wagtendonk 1981
	1976	All year	2.8					van Wagtendonk 1981
	1977	All year	3.0					van Wagtendonk 1981
	1978	All year	3.0					van Wagtendonk 1981
	1979	All year	2.7					van Wagtendonk 1981
Great Smoky Mountains NP backcountry (NC & TN)	1976	All year	2.8	16	73	—— 10 ——		Bratton and others 1977
Great Gulf (NH)	1976	Summer	3.0	— [3]50 —				Leonard and others 1978
Indian Peaks backcountry (CO)	1976	Summer	2.9	11	73	—— 16 ——		Brown and others 1977
Weminuche (CO)	1977	Summer	4.4	9	64	21	7	Haas 1979
Eagles Nest (CO)	1977	Summer	3.6	7	74	16	5	Haas 1979
Rawah (CO)	1977	Summer	4.0	6	72	18	6	Haas 1979
White Mountains (NH)	1977-78	Winter	3.9	7	64	21	7	Taylor and Mackoy 1980
Linville Gorge (NC)	1978	Summer/Fall	4.9	— 73 —		19	8	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	4.4	— 76 —		17	7	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall	3.1	– 85 –		11	3	Roggenbuck and others 1979
Popo Agie (WY)	1978	Summer	3.1	16	69	14	1	Manfredo 1978b
Bridger (WY)	1978	Summer	3.2	16	62	21	1	Manfredo 1978b
Fitzpatrick (WY)	1978	Summer	3.6	20	58	19	3	Manfredo 1978b
Maroon Bells-Snowmass (CO)	1978	Summer	3.3					Haas and others 1982
Great Smoky Mountains NP backcountry (NC & TN)	1979	Summer	2.7	15	74	11	0	Hughes 1985
	1979	Winter	2.6	14	77	9	0	Hughes 1985
	1983	Summer	3.3	16	66	19	0	Burde and Curran 1986
Pusch Ridge (AZ)	1979-80	All year		— [3]74 —				Purdy and Shaw 1981

[1] Percentages may not always add to 100 because of missing data.

[2] Data represent paddling canoeists.

[3] Figures represent percentage of one- and two-person parties.

Method of Travel.—Hiking is the most common travel method in all wilderness areas studied except the Bob Marshall in Montana and the Boundary Waters Canoe Area in Minnesota (table 5). Typically, from 60 to 90 percent of all users of Rocky Mountain wildernesses are hikers. Most of the remaining users travel on horseback, and a few hike with packstock. In the East and in California's Desolation Wilderness, virtually all use is by hikers. Horse use in the East is extremely low where it has been reported, and most studies do not even have a horse-use category.

Exceptions to the predominance of hikers in areas are large, horse-oriented areas like the Bob Marshall, the Great Bear, and perhaps the Teton Wilderness and Idaho Primitive Area (now the Frank Church-River of No Return Wilderness) (Hendee and others 1978). But even in at least some of these areas, hiking use has grown much faster than horse use. For example, the ORRRC study (1962) estimated that 90 percent of all Bob Marshall visitors were horse users in 1959. By 1970 this number was 59 percent (Lucas 1980), and in 1982 there was an even split between the horse users and hikers (Lucas 1985b). The shift away from horse use and toward hiking use was the biggest change that Lucas (1985b) found in his comparison of 1970 and 1982 use and users of the Bob Marshall, Great Bear, and Scapegoat Wildernesses. In 1970, horse users were the clear majority in this three-area complex. By 1982, the situation had reversed, and hikers had become the most common users.

In the Lucas study (1985b) of the Bob Marshall Wilderness complex, hunters were predominantly horse users (79 percent used horses in 1970 and 69 percent in 1982). In contrast, the percentages of nonhunters using horses were 42 and 32 in 1970 and 1982, respectively. Campers were more likely than day-users to be horse users, but here, too, horse use was declining. In 1970, 61 percent of campers and 31 percent of day-users were on horseback. By 1982, these percentages had dropped to 45 percent and 15 percent. Finally, numbers of horses per horse-using party have declined from 12 in 1970 to about nine in 1982.

The Boundary Waters Canoe Area is a unique water wilderness, and there most people travel by boat or canoe. In 1984, 75 percent of all visits May through September were by paddling canoeists, 21 percent were by motor-powered canoes or motorboats, and 4 percent were by hikers.

Outfitter Use.—The number of wilderness visitors who use outfitter services ranges from none in many eastern and small western areas to a majority on such famed whitewater wilderness rivers as the Colorado, Middle Fork of the Salmon, and the Selway. Outfitters are common in many large, horse-oriented western wildernesses, but even in the most popular areas, visitors who employ outfitters are a distinct minority. About 35 percent of all Bob Marshall and Great Bear visitors in 1970 used outfitters (table 6). For all other areas studied, percentage of visitors employing outfitters was less than 8, and in most areas the percentage was less than 1. In the Bob Marshall, close to half the people using horses did not use outfitters (Lucas 1985b). In contrast, only 15 to 20 percent of the horse users in the Great Bear traveled without outfitters.

Outfitting is often associated with hunting and is therefore much more common in the fall. For example, Lucas (1985b) found that 41 percent of the hunters in the Bob Marshall Wilderness complex (an area comprised of the Bob Marshall, Great Bear, and Scapegoat Wildernesses) employed outfitters in 1970; only 20 percent of the nonhunters did. About 29 percent of the Bob Marshall visitors in the summer season used outfitters; this percentage increased to 47 in the fall. Similarly, just 4 percent of the summer Selway-Bitterroot users employed outfitters, but this figure reached 23 percent in the fall.

While outfitting is a sizable industry on many rivers and in large western wildernesses, the percentage of wilderness users employing outfitters appears to be declining. As one example, Lucas (1985b) found that 31 percent of the visitors to the Bob Marshall Wilderness complex used outfitters in 1970, but this percentage decreased to 17 in his 1982 study. A drop occurred in both the summer and fall seasons (table 6).

Length of Stay.—Wilderness visits are typically short. For many small- to medium-sized wildernesses, 1-day visits predominate (Hendee and others 1978). Even in several large western wilderness areas, day visits are the majority. For example, Lucas (1980) found that more than 60 percent of all visits to the Cabinet Mountains and Mission Mountains Wildernesses and the Spanish Peaks Primitive Area of Montana were 1-day visits. Even in the very large Selway-Bitterroot Wilderness in Idaho and Montana, 48 percent of all visits were for a day or less (table 5). At the same time, long trips (trips of a week or more) were rare, accounting for less than 10 percent of visits to all areas except the Bob Marshall and the Great Bear. Half of the western areas studied had no sampled trips longer than 1 week. Average length of stay was typically 2 to 3 days across areas in all regions of the country. Exceptions were the Boundary Waters Canoe Area, Bob Marshall, Great Bear, and Great Smoky Mountains summer users, where lengths of stay averaged from 4 to 5 days. Users of the Popo Agie, Bridger, and Fitzpatrick Wildernesses in Wyoming also had longer stays, perhaps partly due to very long trips by classes from the National Outdoor Leadership School located nearby.

Lucas (1980, 1985b) reported that certain kinds of users have more lengthy stays. Among nine areas that he studied in 1970, horse users averaged a 3.8-day length of stay; this average was 2.2 for hikers. The difference was even greater for the Bob Marshall Wilderness complex, where horse users in 1970 stayed an average of 7.4 days, but hikers stayed for only 2.9 days. Much of the difference between horse users' and hikers' length of stay appears due to differential proportions of day-users. About 32 percent of all hikers were day-users; only 8 percent of the horse travelers stayed such a short time. Hunters and nonhunters had similar lengths of stay in 1970, but by 1982, hunters in the Bob Marshall complex were staying longer than nonhunters (6.7 compared to 4.3 days).

While Hendee and others (1978) suggested that increased travel costs would likely cause wilderness use to shift to fewer but longer trips, recent research suggests that wilderness trips are getting shorter. Lucas (1985b) found visits to the Bob Marshall Wilderness complex to average 5.7 days in 1970; by 1982, trip length had decreased to 4.7 days. Length of stay for horse users dropped from 7.4 days in 1970 to 6.7 days in 1982. The gradual decline in average length of stay in wilderness

Table 5.—Method of travel and length of stay for wilderness visitors by area

Wilderness area (State)	Year	Season	Percent of total visits by travel method				Avg. stay	Percent of total visits of each length (days)			Source
			Hike	Horse	Hike with stock	Other		1	2-3	4+	
Boundary Waters Canoe Area (MN)	1961	Summer					5.1				Lucas 1964a
Bob Marshall (MT)	1964	Summer/Fall					8				Merriam and Ammons 1967
Mission Mountains (MT)	1964	Summer/Fall					2				Merriam and Ammons 1967
Glacier NP backcountry (MT)	1964	Summer/Fall					4				Merriam and Ammons 1967
Eagle Cap (OR)	1965	Summer					3.0				Hendee and others 1968
Three Sisters (OR)	1965	Summer	85	15	0	0	2.2				Hendee and others 1968
Glacier Peak (WA)	1965	Summer	82	18	0	0	2.2				Hendee and others 1968
Bob Marshall (MT)	1970	Summer/Fall	31	59	6	4	5.7	14	23	56	Lucas 1980
Bob Marshall Wilderness complex (MT)	1982	Summer/Fall	57	36	6	4	4.7	22	24	54	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	90	7	2	1	1.6	67	25	7	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	46	42	0	15	4.9	25	13	63	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	97	2	1	0	1.7	62	28	10	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	72	20	7	1	1.9	63	22	12	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	70	20	6	5	2.9	48	25	29	Lucas 1980
Desolation (CA)	1972	All year	99	0	1	0	3.3	17	42	40	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	64	18	12	1	2.9	41	37	22	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71										
—low experience		Summer/Fall						78	13	9	Murray 1974
—moderate experience								46	37	17	Murray 1974
—high experience								35	23	42	Murray 1974
Yosemite NP backcountry (CA)	1972	All year					2.9				van Wagtendonk 1981
	1973	All year					3.0				van Wagtendonk 1981
	1974	All year					2.7				van Wagtendonk 1981
	1975	All year					2.8				van Wagtendonk 1981
	1976	All year					2.6				van Wagtendonk 1981
	1977	All year					2.6				van Wagtendonk 1981
	1978	All year					2.4				van Wagtendonk 1981
	1979	All year					2.8				van Wagtendonk 1981
Boundary Waters Canoe Area (MN)	1974	All year	3	N/A	N/A	[1]97					Hendee and others 1978
	1984	May-Sept.	4	N/A	N/A	[2]96					Superior NF 1984
Great Smoky Mountains NP backcountry (NC & TN)	1976	All year					2.5		64	36	Bratton and others 1977
Weminuche (CO)	1977	Summer					3.4	16	25	59	Brown and Haas 1978
Eagles Nest (CO)	1977	Summer					1.4	36	48	16	Brown and Haas 1978
Rawah (CO)	1977	Summer					2.3	12	53	34	Brown and Haas 1978
White Mountains (NH)	1977-78	Winter						60	— 41 —		Taylor and Mackay 1980
Linville Gorge (NC)	1978	Summer/Fall					2.7	37	52	12	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall					2.8	29	54	18	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall					2.9	24	52	24	Roggenbuck and others 1979
Yosemite NP backcountry (CA)	1978	Winter						80			Gilbert 1980
Popo Agie (WY)	1978	Summer						7	38	55	Manfredo 1978b
Bridger (WY)	1978	Summer						11	31	59	Manfredo 1978b
Fitzpatrick (WY)	1978	Summer						12	16	72	Manfredo 1978b
Maroon Bells-Snowmass (CO)	1978	Summer						38	43	19	Haas and others 1982
Baxter State Park (ME)	1979	Summer					2.7	37	41	22	Reiling and others 1981
Great Smoky Mountains NP backcountry (NC & TN)	1979	Summer	97	3	0	0	3.0		50	50	Hughes 1985
		Winter	100	0	0	0	2.1		74	26	Hughes 1985
Pusch Ridge (AZ)	1979	All year									
	1980	All year						78			Purdy and Shaw 1981
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer					4.5	18	33	50	Burde and Curran 1986

---

[1] 57 percent paddle canoe, 10 percent motor canoe, 28 percent motorboat, 3 percent snowmobile (Lime and Buchman 1975).

[2] 75 percent paddle canoe, 21 percent motor canoe or boat.

Table 6.—Percent of total wilderness visits that employ outfitters

Wilderness area (State)	Year	Season	Visits that use outfitters			Source
			Total	Summer	Fall	
Bob Marshall (MT)	1970	Summer/Fall	35	29	47	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	35			Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	<1			Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	<1			Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	<8			Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	<8			Lucas 1980
Bob Marshall Wilderness complex (MT)	1970	Summer/Fall	31	21	46	Lucas 1985b
	1982	Summer/Fall	17	14	24	Lucas 1985b
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	<8	4	23	Lucas 1980
Desolation (CA)	1972	All year	<1			Lucas 1980

seems due to the presence of proportionately more hikers, fewer horse users, and fewer hunters.

Wilderness Activities.—Recreationists typically participate in a variety of activities during a wilderness trip. For example, Lucas (1980) found that users of nine western wilderness areas averaged 2.5 to 3.1 activities during their visits. Hiking, fishing (where it is possible), and photography were the most common activities (table 7). At least three-fourths of all visitors to virtually all areas hiked. More than half of all visitors fished or took pictures. Hendee and others (1977), however, reported that fishing was often incidental to other activities in wilderness, and was only engaged in for limited times during the trip. Nature study (such as birdwatching, wildlife observation, plant identification, amateur geology) is generally the most common activity after photography. Swimming is common in many places, particularly in areas in the Southeast and California (table 7). Mountain climbing is rare except for a few areas. Hunting in National Forest wildernesses ranges from almost none to fairly common, but is generally less common than might be expected. Of all areas studied, only in the Bob Marshall and the Great Bear did more than 20 percent of the sampled visitors hunt. Even in the fall hunting season, many visitors were not hunters. For example, Lucas (1980) reported that 30 percent of the Selway-Bitterroot users and 80 percent of the Mission Mountains visitors were not hunting during this period.

Activity participation also varies by season of year and type of user (Lucas 1980). Almost all hunting, of course, occurs in the fall; most other activities predominate in the summer. Summer visitors engage in more activities per trip than fall users. Hikers are much more likely to study nature or swim than horse users, but horse travelers tend to hunt and take pictures. Fishing is common among both user groups. Campers engage in a greater variety of activities per visit than day-users, but nature study and hunting are common among single-day visitors.

Lucas (1985b) recently studied activity participation for the Bob Marshall, Great Bear, and Scapegoat Wildernesses and found little change in number and kind of visitor activities between 1970 and 1982. Hiking, fishing, and photography remained important. Of these, only fishing declined, and only slightly. Hunting was the only activity with a substantial change, and it dropped in importance (table 7). These data suggest that there may be a slight shift away from the more consumptive uses of wilderness toward more contemplative activities.

Variation in Use Patterns

While use patterns show considerable similarities across areas, differences do exist. These variations appear to be explained in large measure by some combination of the following 12 variables: region, proximity to population centers, area size, character of the resource, presence of attractions, managing agency, time of establishment as wilderness, extent of area access, time (season and year), trail system configuration, type of user, and tradition.

Region.—Several authors have examined differences in wilderness use patterns by region of the country, and fewer differences have been found than were initially expected (Roggenbuck 1980; Timm 1980; Boteler 1981). Regions of the country with high population concentrations tend to have wildernesses with high use. New England, the Southeast, the Midwest, and California are examples. But each of these regions has some wildernesses with very low use. Time of wilderness use is also significantly influenced by regional location. Early spring or fall color use reduces the typical peaking of summer use in some areas in southern Arizona, southern California, and the Southeast. Weekend peaking appears less severe in the East, at least in summer. Apparently more visitors there use wilderness while on their annual vacation. Horse use and therefore outfitting use are almost nonexistent in eastern wilderness.

Proximity to Population Centers.—Proximity to population centers seems to be an even better predictor of total amount of use than regional location. Also, relationship of the wilderness to nearby urban centers strongly influences distribution of visitor use among the area's trailheads and trail segments. Those entry points and trails closest to population concentrations receive the most use. Weekend peaking of use is much more severe among areas located near population centers, at least in the West.

Area Size.—Size of wilderness has considerable influence on type and distribution of use among trail segments. Extremely large areas are much more likely to have a higher proportion of horse use. Outfitting tends to be more common in large areas. Trail segments deep inside vast areas typically have less use than those in the heart of smaller areas.

Character of the Resource.—The character of the wilderness resource—its ecosystem characteristics—

Table 7.—Wilderness activities participated in by area

Wilderness area (State)	Year	Season	Percent of total visits involving the activity										Source
			Fish	Hunt	Hike	Photography	Nature study	Mountain climbing	Swim	Cross-country skiing	Snow shoeing	Other[1]	
Bob Marshall (MT)	1970	Summer/Fall	61	34	58	58	28	0	11			18	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	61	6	81	45	25	2	15			19	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	62	43	54	53	15	0	4			16	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	74	2	79	56	31	2	18			8	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	41	16	70	53	29	4	9			7	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	62	11	74	53	27	2	20			14	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	43	16	75	58	35	2	17			7	Lucas 1980
Desolation (CA)	1972	All year	48	1	94	54	52	4	46			11	Lucas 1980
Adirondack High Peaks (NY)[2]	1974-75	Winter			25			32		36	19		Snowden 1976
Weminuche (CO)	1977	Summer	52		92	73	42	8					Brown and Haas 1978
Eagles Nest (CO)	1977	Summer	46		94	65	31	4					Brown and Haas 1978
Rawah (CO)	1977	Summer	54		94	73	7	3					Brown and Haas 1978
White Mountains (NH)	1977-78	Winter			45			8		50	28		Taylor and Mackoy 1980
Linville Gorge (NC)	1978	Summer/Fall	15	3	[3]89 [4]48	48	41	26	39				Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	5	5	[3]87 [4]42	48	43	3	25				Roggenbuck and others 1979
Joyce Kilmer/ Slickrock (NC)	1978	Summer/Fall	12	6	[3]91 [4]35	46	47	3	35				Roggenbuck and others 1979
Yosemite NP back-country (CA)	1978	Winter								92			Gilbert 1980
Baxter State Park (ME)	1979	Summer	23		[5]66 [6]51	68	[7]34 [8]67	1				15	Reiling and others 1981
Bob Marshall Wilderness complex (MT)	1982	Summer/Fall	57	16	68	61	28	1	17			15	Lucas 1985b

---

[1] Other includes such activities as horseback riding, river rafting, and camping.
[2] Day trips only.
[3] Hiking on trails.
[4] Hiking off trails.
[5] Mountain hiking.
[6] Gentle terrain hiking.
[7] Birdwatching.
[8] Other wildlife observation.

strongly influences the amount, nature, and distribution of use. Some swamp and lowland wildernesses in the Southeast receive almost no use. (Bradwell Bay in Florida is an example.) Water areas like the Boundary Waters Canoe Area Wilderness and several wildernesses with whitewater rivers have extremely high canoe or boat use and relatively little horse or hiking use. Outfitting is common in these lake and river wildernesses. While off-trail use is low everywhere, it is much higher in alpine areas with trail systems that take visitors above timberline. Finally, the nature of the resource largely explains the extent of such wilderness activities as hunting, fishing, rock climbing, and swimming.

Presence of Attractions.—The presence of attractions such as lakes, mountain peaks, views, and rock climbing opportunities within a wilderness affects the total number of visitors, where visitors go, and what they do. Some wilderness areas in the East and Midwest, regions of high population concentrations, have low use. While reasons for lack of visitation are largely unknown, their lack of special attractions is a likely cause. These areas have apparent naturalness, but they may be "ordinary woods" in the minds of potential visitors. The concentration of travel and camping use around lakes, rivers, views, and ridgelines is common throughout wilderness. This is especially the case in small areas with only a single or a few attractions.

Managing Agency.—Research suggests limited differences in patterns of National Forest and National Park wilderness visitors. National Park visitors are more likely to be alone, to travel in small parties, and they do not hunt (with limited exceptions in Alaska). There are almost certainly fewer horse users in the parks, but we found no data to substantiate this.

Time of Establishment as Wilderness.—The relatively low use of many recently established wilderness areas in the East, Midwest, and West may be due to their lower scenic quality or the presence of fewer attractions, but it may also be that the new areas have not yet become widely known. Several of these areas were designated "wilderness" not so much because of their current recreational popularity, but because of their apparent naturalness, opportunities for solitude, and their potential for providing a more complete ecosystem representation within the Wilderness System.

Extent of Area Access.—Type and degree of access to the wilderness influence amount, nature, and distribution of area use. Most island wildernesses have little or no use, either because there is no public access or because access is strictly controlled. Some wildernesses—the Great Bear and the Frank Church-River of No Return Wildernesses—have airfields within or adjacent to them, and this affects their kind of use and users. Perhaps most important, the kind of access to individual trailheads strongly influences the amount of use that the entry points and their trails receive. Entry points reached only after travel for long distances on dusty, gravel roads filled with "chuck holes" tend to receive less use than those reached over short, good roads.

Time (Season and Year).—As might be expected, season of the year substantially affects amount of use. For virtually all wilderness areas, summer is the season of highest use. But season of use also influences what people do in wilderness, method of travel, weekly pattern of use, and length of stay. Hunting is a fall activity almost everywhere. Because of the large number of hunters, fall has the highest proportion of horse users. Length of stay tends to be somewhat longer in fall but shorter in winter. Winter activities include cross-country skiing and snowshoeing, and peaking of weekend use seems even more severe in winter than in other seasons.

Trail System Configuration.—Since virtually all wilderness users stick to established trails, the trail system has a strong influence on where people travel and where they camp. Some wildernesses have a single trail that leads from an entry point to an area attraction, with few branching alternative routes. Such trails tend to become heavily used, two-way traffic corridors. Other areas have multiple trails that converge at a single point. Such points, especially at attractions, tend to become popular for eating, resting, and camping.

Type of User.—The type of user—hiker or horse user, day-user or camper, hunter or nonhunter—is significantly related to wilderness use patterns. Horse users come in larger groups, stay longer, and penetrate deeper into the wilderness than hikers do. Horse travelers also are more likely to hunt and take photos, while hikers are more likely to engage in swimming and nature study. Hunters are predominantly horse users, and are more likely to be outfitted, come in the fall, and stay longer. Campers are more likely than day-users to be horse users, travel in larger groups, and engage in more activities. River rafters tended to visit the wilderness in large groups and be outfitted.

Tradition.—Finally, while no hard data are available to substantiate the idea, some wilderness areas seem to have certain users because they traditionally have had those uses. The Bob Marshall has the image of a horse area; the Boundary Waters Canoe Area is perceived as a canoe area. Perhaps because of past use histories or images in the minds of potential users, these areas continue to attract traditional user groups.

User Characteristics

Age.—Wilderness users tend to be young, younger than the general population. Table 8 indicates that there is a substantial overrepresentation of 16- to 25-year-olds and 26- to 35-year-olds among wilderness visitors compared to the general population in virtually all wilderness areas studied. However, the 36-45 age group is also overrepresented in most areas, and the 46-55 age category is common in wilderness, being present in proportions similar to their numbers in the general population. When wilderness allocation decisions are debated, opponents often argue that wilderness designation denies access to the old and the young (Lucas 1980). Table 8 suggests that the 56 and older age groups are substantially underrepresented, but older people have lower participation rates in all types of outdoor recreation (Bureau of Outdoor Recreation 1972). Older people do visit wilderness. For example, 10, 11, and 12 percent of the 1970 wilderness visitors in the Bob Marshall, Selway-Bitterroot, and Great Bear Wildernesses, respectively, were 56 years or older. While table 8 suggests that young children are substantially underrepresented in most wildernesses, this is in part an artifact of data collection methods. Typically, the referenced surveys did not include children under about 16 years of age. Lucas (1980) reported that about half of all wilderness user groups in the nine areas he studied contained children.

The few studies done in the East and Southeast suggest age distributions similar to those in the Rockies and the Pacific Northwest. If anything, users in the East are slightly younger. Lucas (1980) reported little association between season of visit and age of visitor, but his data generally reflect studies of only summer and fall users. While data are almost nonexistent, research in the Great Smoky Mountains National Park backcountry and in the White Mountains of New Hampshire suggests that winter users are younger. Finally, Lucas (1980) found that horse users were somewhat older than hikers and campers were somewhat younger than day-users in the nine western areas he studied.

Gender.—Table 8 indicates most wilderness visitors are males; percentages typically range from 70 to 85 percent. In smaller, hiking-oriented areas, the number of males is often at the lower end of this range; but in the larger, horse-oriented areas, percentages are at the upper end (Hendee and others 1978). Lucas (1980) indicated that for the fall season, particularly in popular hunting wildernesses, the percentages of males are even higher. The limited data on winter wilderness visitors are mixed. Hughes (1985) surveyed almost no women in the backcountry of Great Smoky Mountains National Park during her winter use study, but Snowden (1976) and Taylor and Mackoy (1980) found the proportion of winter female

Table 8.—Age and gender of wilderness visitors[1]

Wilderness area (State)	Year	Season	Age (percent of total)							Percent male	Source
			1-15	16-25	26-35	36-45	46-55	56-64	65+		
Boundary Waters Canoe Area (MN)[2]	1960	Summer	30	42	13	13		2		82	Lucas 1964
Glacier Peak (WA), Eagle Cap (OR), and Three Sisters (OR)	1965	Summer	3	21	24	23	21	5	2	82	Hendee and others 1968
Bob Marshall (MT)	1970	Summer/Fall	13	17	21	25	13	10		80	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	8	40	22	12	12	6		70-80	Hendee and others 1978
Great Bear (MT)	1970	Summer/Fall	0	7	30	32	18	12		87	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	9	24	25	20	14	9		70-80	Hendee and others 1978
Spanish Peaks (MT)	1970	Summer/Fall	26	29	17	17	9	3		70-80	Hendee and others 1978
Scapegoat (MT)	1970	Summer/Fall	4	29	25	24	11	8		70-80	Hendee and others 1978
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall	0	50	20	15	9	6		70	Murray 1974
Selway-Bitterroot (ID & MT)	1971	Summer/Fall	4	27	24	19	14	11		70-80	Hendee and others 1978
Desolation (CA)	1972	All year	29	28	18	12	10	2		—	Hendee and others 1978
Great Smoky Mountains NP backcountry (NC & TN)	1973	Summer	0	34	31	19	16			92	Burde and Curran 1986
Adirondack High Peaks (NY)	1960	Summer								83	Snowden 1976
	1974-75	Winter								78	Snowden 1976
Eagles Nest (CO)	1977	Summer	62			37			1	78	Brown and Haas 1978
Rawah (CO)	1977	Summer	76			22			1	79	Brown and Haas 1978
Weminuche (CO)	1977	Summer	61			37			1	80	Brown and Haas 1978
Popo Agie (WY)	1978	Summer	7	78		14		1		75	Manfredo 1978b
Bridger (WY)	1978	Summer	17	71		10		3		72	Manfredo 1978b
Fitzpatrick (WY)	1978	Summer	1	74		20		5		72	Manfredo 1978b
Linville Gorge (NC)	1978	Summer/Fall	11	31	37	13	7			73	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	12	27	32	16	13			75	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC & TN)	1978	Summer/Fall	10	34	36	12	8			69	Roggenbuck and others 1979
White Mountains (NH)	1977-78	Winter	0	32	37	19	8	4		74	Taylor and Mackoy 1980
	?	Summer	0	37	29	17	10	6		64	Taylor and Mackoy 1980
Great Smoky Mountains NP backcountry (NC & TN)	1979	Winter	0	38	45	10	6	2	0	99	Hughes 1985
Baxter State Park (ME)	1979	Summer	22	30	25	10	6	7		?	Reiling and others 1981
Bob Marshall (MT)	1982	Summer/Fall	13	18	24	23	22			70	Lucas 1985b
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer	0	34	38	15	9	4		89	Burde and Curran 1986
U.S. population	1960		33	13	13	12	12	8	9		U.S. Census
	1970		31	17	12	11	11	18			U.S. Census
	1978		25	19	15	11	10	20			Reiling and others 1981

---

[1] Age data on wilderness visitors and U.S. population were interpolated to fit table's age categories.
[2] Data are for paddle canoeists.

Table 9.—Education level distribution as a percent of total wilderness visitors by area

Wilderness area (State)	Year	Season	Years of schooling completed 0-8	9-11	12	13-15	16	17+	Source
Boundary Waters Canoe Area (MN)[1]	1960	Summer	0	— 21 —		— 54 —		25	Lucas 1964a
Glacier Peak (WA)	1965			— 35 —		— 36 —		29	Hendee and others 1968
Eagle Cap (OR)	1965			— 38 —		— 38 —		24	Hendee and others 1968
Three Sisters (OR)	1965			— 36 —		— 34 —		30	Hendee and others 1968
High Sierra (CA)	1960			— 18 —		— 49 —		33	Hendee and others 1968
Bob Marshall (MT)	1970	Summer/Fall	4	14	22	17	11	31	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	3	22	26	24	8	15	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	3	6	29	15	24	24	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	4	14	15	16	12	35	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	2	10	21	26	8	30	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	4	13	30	24	9	18	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall		— 20 —		— 44 —		36	Murray 1974
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	3	10	27	23	9	27	Lucas 1980
Desolation (CA)	1972	All year	0	5	12	29	11	42	Lucas 1980
Cranberry back-country (WV)	1972	Spring/ Summer/Fall	— 22 —		41	15	— 22 —		Echelberger and Moeller 1977
Adirondack High Peaks (NY)	1960	Summer		— 16 —		— 57 —		22	Snowden 1976
	1974-75	Winter		— 19 —		— 53 —		28	
Weminuche (CO)	1977	Summer	1	6	14	24	18	39	Brown and Haas 1978
Rawah (CO)	1977	Summer	0	6	11	24	25	34	Brown and Haas 1978
Eagles Nest (CO)	1977	Summer	0	2	10	27	26	33	Brown and Haas 1978
Yosemite NP backcountry (CA)	1978	Winter					— 92 —		Gilbert 1980
Linville Gorge (NC)	1978	Summer/Fall	— 1 —		15	27	20	37	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	— 3 —		19	26	21	31	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall	— 0 —		14	25	19	41	Roggenbuck and others 1979
Baxter State Park (ME)[2]	1979	Summer	— 2 —		15	18	22	43	Reiling and others 1981
Bob Marshall Complex (MT)	1982	Summer/Fall	2	7	22	23	21	26	Lucas 1985b
U.S. population	1960			— 92 —			— 8 —		Hendee and others 1968
	1970		28	17	34	10	— 11 —		U.S. Census
	1980		17	14	37	15	— 17 —		U.S. Census

[1] Data represent paddling canoeists.
[2] Education level of head of household.

visitors in their eastern study areas to be similar to proportions in other seasons of the year. The 20 to 25 percent women found in most studies do, however, represent a significant minority in wilderness. Numbers of women may be increasing. For example, Lucas (1985b) reports that the proportion of female visitors to the Bob Marshall Wilderness grew from 20 percent in 1970 to 30 percent in 1982.

Education.—The most distinguishing characteristic of wilderness users is their high education level. As table 9 indicates, at least 25 percent of the visitors to most areas studied either are attending or have attended graduate school. In most areas, about 40 percent have completed college; in some areas this number exceeds 50 percent. This far exceeds the schooling for the United States general population, where 11 and 18 percent completed college or attended graduate school in 1970 and 1980, respectively. In most areas the proportion of wilderness visitors going to school beyond college is greater than the proportion of the U.S. population that goes beyond high school (Lucas 1980). Also, the difference between wilderness visitors and the general population is even larger than these figures suggest, for the U.S. census data are based on education levels of people 25 or more years of age. Wilderness surveys generally include individuals down to 16 years old. Many of these are students and have not yet completed their schooling, so their education attainment usually is lower than it would be at 25.

Education levels vary a great deal among study areas, but all are much higher than both the national average and the average for their State. Variation across areas seems due in part to the time of the study (with the higher educational levels of areas studied most recently reflecting the growing educational levels in the country), the overall education levels of the area's State (thus the large number of visitors to Desolation Wilderness, CA, with graduate education), and the educational levels of nearby communities. Montana areas with adjacent small forest industry towns have visitors with lower educational levels than wildernesses near university towns (Lucas 1980). Educational levels also vary with other wilderness

Table 10.—Occupational distribution as a percent of total wilderness visitors by area

Wilderness area (State)	Year	Occupation									Source
		Professional and technical	Business manager	Craftsman and operations	Farmer	Clerical, sales, and service worker	Military	Housewife	Student	Other	
Boundary Waters Canoe Area (MN)[1]	1960	71	13	2	1	7				6	Lucas 1964a
Bob Marshall (MT)	1964	18	28	3		15	9		27		Merriam and Ammons 1967
Mission Mountains (MT)	1964	49	7	4		16			22	2	Merriam and Ammons 1967
Glacier NP back-country (MT)	1964	39	16			13			32		Merriam and Ammons 1967
Bob Marshall (MT)	1970	32	11	15	3	9	2	9	17	2	Lucas 1980
Cabinet Mountains (MT)	1970	20	2	16	2	7	2	9	31	11	Lucas 1980
Great Bear (MT)	1970	33	5	14	5	11	1	9	4	8	Lucas 1980
Mission Mountains (MT)	1970	41	2	15	2	5	0	9	20	5	Lucas 1980
Spanish Peaks (MT)	1970	31	5	10	5	8	1	7	34	2	Lucas 1980
Scapegoat (MT)	1970	23	6	10	6	9	7	9	26	4	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	60	17		6			12		5	Murray 1974
Selway-Bitterroot (MT & ID)	1971	26	4	14	5	10	0	9	22	10	Lucas 1980
Desolation (CA)	1972	39	1	7	0	11	3	1	30	8	Lucas 1980
Linville Gorge (NC)	1978	47	14	5	0	11		1	17	5	Roggenbuck and others 1979
Shining Rock (NC)	1978	29	29	9	1	12		2	10	8	Roggenbuck and others 1979
Joyce Kilmer/ Slickrock (NC)	1978	42	13	8	1	14		3	14	5	Roggenbuck and others 1979
Cranberry back-country (WV)	1972	36			40				24		Echelberger and Moeller 1977
Adirondack High Peaks (NY)	1974-75	35	5			3			43	14	Snowden 1976
White Mountains (NH)	1977-78	36	10						31	24	Taylor and Mackoy 1980
Bob Marshall complex (MT)	1982	37	8	18	5	10	2	4	11	5	Lucas 1985b
U.S. population	1958	9	12	17	6	12				44	
	1970	6	3	22	3	28	1	25	5	7	
	1980	9	7	21	2	23	1	21	4	12	

[1] Data represent paddle canoeists.

user characteristics. Day-users were slightly more educated than campers, and nonhunters had higher education levels than hunters in the Bob Marshall Wilderness complex (Lucas 1985b). More generally, hikers were more educated than horseback riders or river rafters, and summer visitors were more educated than fall visitors (Lucas 1980, 1985b).

Occupation.—Persons in the professional and technical occupations and students were the majority of visitors to most areas (table 10). In many areas 30 to 40 percent of all visitors were professional or technical workers, and from 20 to 30 percent were students. Professionals in wilderness exceeded the proportion in the U.S. population by four to five times, and students were four to seven times more numerous in wilderness than in the population. Housewives and clerical, sales, and service workers (many of whom are female) were the most underrepresented in wilderness. These patterns reflect the education and gender distribution of wilderness visitors discussed earlier.

Hikers were more likely to be professionals, technical workers, or students than were horse users. In contrast, horse travelers were much more likely to be "blue collar" craftsmen, laborers, and in some areas, farmers. Students formed a larger proportion of wilderness campers than of day-users. Finally, professional and technical workers and housewives were relatively more common in the summer than in the fall. Winter users were most likely to be students.

Table 11.—Distribution of family income as a percent of total wilderness visitors by area

Wilderness area (State)	Year	Season	Income (dollars) <5,000	5,000-9,999	10,000-14,999	15,000-24,999	25,000-49,999	50,000+	Source
Boundary Waters Canoe Area (MN)[1]	1960	Summer	27	45	19	3	6	0	Lucas 1964a
Bob Marshall (MT)	1970	Summer/Fall	6	30	23	29	14		Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	12	45	28	12	4		Lucas 1980
Great Bear (MT)	1970	Summer/Fall	9	19	22	30	20		Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	15	32	26	16	11		Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	17	29	26	17	11		Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	11	42	29	14	7		Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall	10	24	23	44			Murray 1974
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	12	37	25	17	10		Lucas 1980
Desolation (CA)	1972	All year	11	24	19	35	11		Lucas 1980
Cranberry backcountry (WV)	1972	Spring/ Summer/Fall	12	32	35	21			Echelberger and Moeller 1977
Four California Wilderness Areas (CA)[2]	1973		27	15	18	26	14		Hendee and others 1978
Adirondack High Peaks (NY)	1974-75	Winter	10	19	23	27	17	4	Snowden 1976
White Mountains (NH)	1977-78	Winter	5	12	20	26	30	7	Taylor and Mackoy 1980
Baxter State Park (ME)	1979	Summer	16		14	33	37		Reiling and others 1981
U.S. Population	1960 families		42	43	11	3	1	0.1	U.S. Department of Commerce, 1983 (Statistical Abstract 1982-83)
	1970 families		19	32	27	18	4	0.5	
	1980 families		6	13	14	28	32	7	

[1]Data represent paddle canoeists.
[2]Specific areas unidentified.

In Lucas' (1985b) comparative study of visitors to the Bob Marshall Wilderness complex, he found such professional workers as accountants, engineers, doctors, nurses, teachers, religious workers, and scientists to be even more common in 1982 than in 1970. Farmers and craftsmen were also slightly more frequent, and, somewhat surprisingly, the percentage of students and housewives had dropped.

Income.—As a group, wilderness visitors have above average incomes (as do most outdoor recreationists) (table 11). This reflects the high education levels and the high proportion of users with professional occupations. There is, however, considerable variation by area. Some areas (such as the Mission Mountains, Spanish Peaks, Scapegoat, Selway-Bitterroot, and Cranberry), have visitors with incomes close to the national average, but others far exceed it. Most eastern area users have high incomes compared to the general U.S. population, as do Desolation visitors in California. These differences reflect the variation in the population's income in the States in which areas are located. Thus, many Montana visitors reflect the country's national income average, but they still exceed their State's average. In some instances, higher than average income figures are in part the result of comparing user incomes in the late 1970's with a 1970 standard. Also, some areas' high incomes result from the type of user they attract. For example, Great Bear is an area with considerable airplane access and the Bob Marshall has heavy horse and outfitter use (Lucas 1980); these uses may be beyond the means of lower income people. The few studies of winter wilderness users suggest high incomes for them as well.

These high income figures have led some to suggest that wilderness is accessible only to the very wealthy. This, however, is not supported by the data. For most areas studied in 1970, from one-third to one-half of all users had annual incomes below $10,000, at a time when the median U.S. income was about $9,000 (Lucas 1980). In addition, it usually costs little to actually use wilderness. Most visitors travel only relatively short distances to reach their wilderness destination (Lucas 1980), and costs per wilderness use-day in the early 1970's were usually low—only about $10 (Hendee and others 1978).

Place of Residence.—Visitors to most wilderness areas are from the State in which the area is located (table 12). In the West, except for the nationally known Glacier National Park backcountry and Colorado's Weminuche Wilderness (located in close proximity to Utah, Arizona, and New Mexico), more than half of all areas' visitors were in-State residents. For many areas, State residents exceeded 75 percent. For California areas, the number was 84 percent or higher. In addition, Lucas (1985b) found that most resident visitors come from the State's regions closest to the wilderness. For example, 60 percent of all visitors to the Bob Marshall Wilderness complex were from Montana, and 54 percent of all its visitors were from northwestern Montana—the region where the areas are located. Thus, in the West, it appears that wilderness recreational benefits are primarily regional in nature.

Table 12.—Area of residence and membership in wilderness, conservation, and outdoor clubs as a percent of total visitors by area

Wilderness area (State)	Year	Season	Visitor residence				Club membership	Source
			In-State[1]	Out-of-State	Urban	Rural		
Boundary Waters Canoe Area (MN)[2]	1960	Summer	46	54				Lucas 1964a
Bob Marshall (MT)[3]	1964	Summer/Fall	68	32				Merriam and Ammons 1967
Mission Mountains (MT)[3]	1964	Summer/Fall	80	20				Merriam and Ammons 1967
Glacier NP back-country (MT)	1964	Summer/Fall	19	81				Merriam and Ammons 1967
Glacier Peak (WA)	1965	Summer					25	Hendee and others 1968
Eagle Cap (OR)	1965	Summer					32	Hendee and others 1968
Three Sisters (OR)	1965	Summer					32	Hendee and others 1968
Allagash Wilderness	1966		63	37				Cieslinski 1980
Waterway (ME)	1973	All year	48	52				Cieslinski 1980
	1978		51	49				Cieslinski 1980
Bob Marshall (MT)	1970	Summer/Fall	64	36	65	35	30	Lucas 1980
	1982	Summer/Fall	57	43	61	39	25	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	75	25			24	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	53	47			38	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	74	26			27	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	71	29			28	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	86	14			26	Lucas 1980
Selway-Bitterroot (MT & ID)	1970	Summer/Fall	64	36			27	Lucas 1980
Desolation (CA)	1972	All year	93	7			35	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall	49	51	68	32		Murray 1974
Yosemite NP back-	1973	?	84	16				van Wagtendonk 1981
country (CA)	1976	Summer	12	88				Leonard and others 1978
Great Gulf (NH)								
Indian Peaks back-	1976	Summer	77	23				Haas 1978a
country (CO)	1976-77	Winter	96	4				Haas 1978a
Weminuche (CO)	1977	Summer	33	66	84	15		Brown and Haas 1978
Rawah (CO)	1977	Summer	72	26	87	14		Brown and Haas 1978
Eagles Nest (CO)	1977	Summer	75	22	79	20		Brown and Haas 1978
White Mountains (NH)	1977-78	Winter	27	74			54	Taylor and Mackoy 1980; Taylor and Spencer 1980
Linville Gorge (NC)	1978	Summer/Fall			67	33	38	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall			68	32	38	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall			77	23	57	Roggenbuck and others 1979
Baxter State Park (ME)	1979	Summer	52	48				Reiling and others 1981
Great Smoky Mountains NP	1979	Summer	35	65				Hughes 1985
backcountry (NC & TN)		Winter	46	54				Hughes 1985
Great Bear (MT)	1982	Summer/Fall	63	37	57	43		Lucas 1985b
Scapegoat (MT)	1982	Summer/Fall	64	38	67	33		Lucas 1985b

[1] In-State means visitor resides in area's State(s).

[2] Data for paddle canoeists.

[3] Figures estimated from report's bar graphs.

In the East, many more wilderness visitors were from out of State. This likely reflects both the smaller size of eastern States and the relative scarcity of wilderness resources there. These areas are highly accessible, and demand is high.

Lucas (1980) reported mixed results when he related place of residence to other wilderness use and user characteristics. He expected that horseback travelers, fall visitors, and overnight visitors would more often be out-of-State visitors. In his 1970 study of the Bob Marshall complex, he found more horse users (41 percent) than hikers (30 percent), more hunters (42 percent) than nonhunters (29 percent), and more campers (34 percent) than day-users (16 percent) to be from out of State. In the 1970 sample there were no out-of-State river rafters. By 1982, user characteristics had changed. Out-of-State horse users and hikers represented about an equal proportion within their use category (about 40 percent), and out-of-State raft use had reached 27 percent. The percent of nonresident hunters remained the same (42 percent), but the percent of out-of-State nonhunters grew to 39 percent. Percentages of nonresident campers and day-users grew to 42 and 29, respectively, in the 1982 study.

Urban/Rural Residence.—Most wilderness visitors live in urban areas. Table 12 indicates that for the areas for which data are available, more than 60 percent of all wilderness users reside in urban areas. Brown and Haas (1978) reported that about 80 percent of visitors to three Colorado areas they studied were urban residents. Lucas (1980) reported a range of 45 to 90 percent urban residents for the nine western areas he studied. Of these, Desolation Wilderness in California had the most urban clientele, and the Great Bear and Cabinet Mountains had the least. In most areas studied (Lucas 1980, 1985b), hikers and rafters were substantially more urban than horsemen, and hunters were less urban than nonhunters.

The high amount of use of wilderness by urbanites does not, however, suggest that wilderness users are disproportionately urban. Most of the U.S. population (about 74 percent) is urban, and urban residents appear to use wilderness in proportions about equal to their numbers of the general population. For example, Lucas (1985) found that 50 percent of the Montana visitors to the Bob Marshall complex were from urban areas; 51 percent of Montana population is urban. At the same time, 74 percent of the area's out-of-State visitors were urban residents, a proportion equal to that of the urban population of the United States.

Club Membership.—Some have suggested that wilderness visitors are predominantly members of specialized interest groups such as wilderness, conservation, and outdoor recreation clubs. Research refutes this contention. For most areas for which data are available, only 20 to 35 percent of the users belong to any sort of outdoor club (table 12). In the East, these percentages seem somewhat higher. For example, over 50 percent of both winter recreationists in the White Mountains backcountry and the visitors to Joyce Kilmer-Slickrock Wilderness belong to a conservation or recreation club. This likely reflects the unusually high educational levels, incomes, and urban nature of the areas' visitors.

Lucas (1980) examined the type of outdoor club to which members belonged, and found considerable variation across areas. In many areas, visitors belonged primarily to local rod and gun clubs. For example, only about 28 percent of the club members among visitors to the Bob Marshall Wilderness complex belonged to a wilderness-oriented club (Lucas 1985b). In contrast, over half of the outdoor club members among visitors to the Desolation and Mission Mountains Wildernesses and the Spanish Peaks Primitive Area belonged to a national wilderness-oriented organization like the Sierra Club or The Wilderness Society. Lucas (1985b) also found that Bob Marshall horsemen were more likely to be club members than were hikers. Also, while hunters and nonhunters in the Bob Marshall were similar in percentage of outdoor club membership, hunters were less likely to be members of wilderness organizations and more likely to belong to rod and gun clubs.

Previous Wilderness Experience.—As table 13 indicates, most wilderness users have considerable experience. For the western areas, between 70 and 90 percent of visitors had made at least one previous visit to a wilderness or wildernesslike area. These percentages were slightly lower for some eastern areas. The amount of previous experience in the study area varied a great deal. For many areas, about 30 or 40 percent had made no previous visits to the study area, but in some wildernesses, this number reached 60 percent. The areas with the high percentage of first-time users tended to be those that had been designated as wilderness more recently. Many areas also had between 20 and 30 percent of their visitors who had made six or more visits. These percentages dropped to 10 to 20 for some more recently established areas.

Lucas (1980) and Hendee and others (1968) have also reported age of first visit to wilderness, the average number of visits to wilderness per year, and number of days spent in wilderness for several western wilderness areas. Typically, between one-third and one-half of the wilderness users made their first visit before their 16th birthday. Parents were important in introducing their children to wilderness, but more often visitors first went to wilderness with a friend or organization. The parents' influence might be greatest through their car camping practices. Between 50 and 60 percent of the wilderness visitors studied said their parents took them car camping when they were young. In comparison, only about 20 percent of the national population car camps.

Visitors averaged three or four wilderness visits per year, and spent a total of 6 to 10 days in wilderness (Lucas 1980). This suggests fairly frequent and fairly short trips. Hikers in the Bob Marshall Wilderness complex tended to make more trips each year than horse users, but their trips were shorter (Lucas 1985b). Hikers also were more experienced, and were introduced to wilderness at a younger age.

Type of Group.—Wilderness user groups composed of the family or family and friends make up the majority of all groups in virtually all areas (table 14). An exception to this are users of the three wilderness areas studied in western Wyoming (Manfredo 1978b); here, classes from the National Outdoor Leadership School contribute to low proportions of families. About half of all groups contain children. Family groups by themselves often account for about 40 percent of all groups. The second most frequent user group overall—and the most frequent in Montana's Great Bear, Wyoming's Popo Agie, Bridger, and Fitzpatrick Wildernesses, and Great Smoky Mountains National Park backcountry—are groups of friends. Organized groups or clubs like outing clubs, Boy Scout or Girl Scout groups, or church groups generally make up 10 percent or less of all groups. In many areas such groups account for less than 5 percent. The percentage of visitors who are alone varies somewhat by area, but in most places is less than 10 percent. In some areas, almost no one travels alone. Exceptions are user groups in the Great Smoky Mountains, Eagles Nest in Colorado, and the Popo Agie, Bridger, and Fitzpatrick in Wyoming, where between 10 and 20 percent are alone.

The patterns of type of group vary by method of travel, day or overnight use, and season of use (Lucas 1985b). In the Bob Marshall Wilderness complex the few solitary visitors are more likely to be hikers than horse users. Summer visitors were twice as likely to be alone, and day-users in the wilderness complex were more likely groups of friends, but by 1982 the proportion of family groups and groups of friends was similar for horse users and hikers. Groups of friends were more numerous in fall in the 1970 study, but by 1982, family groups were as common in the fall as in the summer. These figures and trends suggest that the predominance of the family is growing in wilderness, that family use is spreading more uniformly across seasons and travel patterns, and that strengthened family ties may be an increased benefit of wilderness.

Table 13.—Previous wilderness experience as a percent of total visitors by area

Wilderness area (State)	Year	Season	Previous visits to wilderness	Previous visits to study area				Source
				0	1-2	3-5	6+	
Boundary Waters Canoe Area (MN)[1]	1960	Summer		— 13 —				Lucas 1964a
Bob Marshall Wilderness complex (MT)	[2]1970	Summer/Fall	78	45	18	17	20	Lucas 1980
	[2]1982	Summer/Fall	78	56	16	14	14	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	85	37	17	13	33	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	75	61	13	7	19	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	80	45	21	13	21	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	81	50	17	10	23	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	73	61	17	9	13	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	76	43	13	14	30	Lucas 1980
Desolation (CA)	1972	All year	89	30	23	17	30	Lucas 1980
Cranberry backcountry (WV)	1972	Spring/Summer/Fall		— 75 —				Echelberger and Moeller 1977
Adirondack High Peaks (NY)	1974-75	Winter	70	0	59	24	17	Snowden 1976
Indian Peaks backcountry (CO)[3]	1976	Summer		51	24	14	11	Brown and others 1977
Weminuche (CO)[3]	1977	Summer		30	— 54 —		16	Haas 1978b
Eagles Nest (CO)[3]	1977	Summer						Manfredo and Haas 1978
Dillon District[4]				45	22	23	10	
Holy Cross District[4]				31	20	28	21	
Rawah (CO)[3]	1977	Summer		60	20	6	4	Manfredo 1978a
Linville Gorge (NC)	1978	Summer/Fall	66	39	11	18	33	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	43	35	14	21	30	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall	82	60	12	19	9	Roggenbuck and others 1979
Popo Agie (WY)[3]	1978	Summer		55	30	10	5	Manfredo 1978b
Bridger (WY)[3]	1978	Summer		62	23	8	7	Manfredo 1978b
Fitzpatrick (WY)[3]	1978	Summer		78	16	3	3	Manfredo 1978b
Maroon Bells-Snowmass (CO)[3]	1978	Summer		68	21	— 11 —		Haas and others 1982
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer		34	24	13	28	Burde and Curran 1986

[1] Data represent paddle canoeists.

[2] Bob Marshall complex includes the Bob Marshall, Great Bear, and Scapegoat Wildernesses.

[3] Experience levels refer to visits to the study area within the past 12 months.

[4] Previous visits categories are 0, 1, 2-6, 7+.

Wilderness Knowledge

Research to determine the knowledge base of wilderness visitors and the general public is scarce. This knowledge may influence attitudes and, especially, behavior concerning wilderness and has important implications for understanding wilderness use and managing it.

There are a few studies that provide information on three types of knowledge relative to wilderness: (1) wilderness definitions, (2) appropriate practices in wilderness and related regulations, and (3) the natural role of wildfire. There is apparently no research on public knowledge of alternative wilderness or similar nonwilderness opportunities, or alternative locations within a particular wilderness, although there have been several studies of how visitors respond to information about various parts of a wilderness (Schomaker 1975; Lime and Lucas 1977; Lucas 1981; Roggenbuck and Berrier 1981; Krumpe and Brown 1982).

Wilderness Definitions.—In general, wilderness visitors have more accurate information about wilderness definitions than the general public has, and the public in areas close to a number of wildernesses has more accurate information than people who live far from wilderness. Young (1978) found that the general public in Illinois had little knowledge of the basic definitions of wilderness. Many were unaware that logging and mechanical recreation generally were banned. Keegan and others (1982) found higher knowledge of wilderness characteristics among the general public in Montana; 70 percent of those polled reported they had personally visited some of the State's many wildernesses. About 16 percent had visited a classified wilderness in the previous year, and about 40 percent had done so at some time.

Stankey (1973) and Robertson (1981) both found fairly high knowledge levels among wilderness visitors, although Stankey reported considerable variation among his four study areas.

Table 14.—Type of group as a percent of total groups by area

			Type of group						
Wilderness area (State)	Year	Season	Family	Family and friends	Friends	Organized group or club	Alone	Information missing	Source
Glacier Peak (WA), Eagle Cap (OR), Three Sisters (OR)	1965		47		38	8	7		Hendee and others 1968
Bob Marshall Wilderness complex (MT)	1970	Summer/Fall	43	15	30	2	6	4	Lucas 1980
	[1]1982	Summer/Fall	55		36	3	6	0	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	40	15	33	5	5	1	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	24	14	62	0	0	0	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	46	17	29	2	2	5	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	38	13	35	4	5	5	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	36	21	29	8	6	1	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	40	14	37	3	5	1	Lucas 1980
Desolation (CA)	1972	All year	33	17	32	8	5	5	Lucas 1980
Boundary Waters Canoe Area (MN)	1974	Summer	61		27	11	1		Hendee and others 1978
Weminuche (CO)	1977	Summer	44	13	27	11	5		Haas 1978b
Eagles Nest (CO)	1977	Summer							Manfredo and Haas 1978
Dillon District			40	10	37	2	11		
Holy Cross District			28	8	40	4	20		
Rawah (CO)	1977	Summer	47	5	37	3	7		Manfredo 1978a
Popo Agie (WY)	1978	Summer	25	14	47		15		Manfredo 1978b
Bridger (WY)	1978	Summer	27	7	49		16		Manfredo 1978b
Fitzpatrick (WY)	1978	Summer	19	7	53		20		Manfredo 1978b
Maroon Bells-Snowmass (WY)	1978	Summer	42	10	37	1	10		Haas and others 1982
Baxter State Park (ME)	1979	Summer	[2]56				3		Reiling and others 1981
			[3]51				8		
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer	40		44		16		Burde and Curran 1986

[1]Bob Marshall complex includes Bob Marshall, Great Bear, and Scapegoat Wildernesses.
[2]Resident figures.
[3]Nonresident figures.

Appropriate Practices in Wilderness and Related Regulations.—McAvoy and Hamborg (1984) found Boundary Waters Canoe Area Wilderness visitors were quite knowledgeable about regulations in the area. Persons reporting the Forest Service as their main source of information had higher knowledge levels. Brochures were effective at communicating; personal contact added little. Robertson (1981) also found fairly high knowledge of recommended low-impact camping practices among visitors to the Three Sisters Wilderness in Oregon, and she found that knowledge predicted behavior far better than other variables tested.

Hill (1975) found limited knowledge of low-impact practices among University of Utah students who were beginning a class in backpacking skills. Littering behavior was the only topic about which students had good knowledge. Lucas (1985b) found an increase in Bob Marshall Wilderness complex visitors' knowledge about garbage handling (packing it out rather than burying it) from 1970 to 1982. In 1970, most visitors thought burying was appropriate, but by 1982 this practice was rejected by a 2 to 1 margin. Stankey (1979) reported that 40 percent of the 1973 visitors to the San Gorgonio and San Jacinto Wildernesses in California were unaware of a use rationing system instituted that same year.

The Natural Role of Wildfire.—Stankey (1976) found poor knowledge about wilderness fire and its effects, but similar to Robertson (1981), he found that support for a policy of allowing fire to more nearly play its natural role was associated with greater knowledge of fire. McCool and Stankey (1986) found that Selway-Bitterroot Wilderness visitors' knowledge of wilderness fires increased considerably from 1971 to 1984. The positive association of knowledge about fire and attitudes supporting prescribed fire found in the earlier study was confirmed for 1984 visitors.

Use Measurement

Reasonably accurate basic recreational use data are widely recognized as essential to professional management of most wildernesses. Despite the importance of use data, for years managers of many areas have made do with data of low accuracy.

Managers' Use Estimation Techniques.—Five general methods of estimating wilderness recreational use are commonly used by managers:

1. Casual observation and best guesses. Managers or fieldworkers try to recall how many visitors they saw, wherever and whenever they happened to be in or around the wilderness, and then conjure an estimate, usually using last year's reported use as a starting point. Use of this method is motivated by agency requirements for a report of use each year, not by any need to employ use data in management activity. This description may seem harsh, but this method has been one of the most commonly used systems throughout the last 20 years.

2. Recorded observation and systematic "guesstimates." Agency personnel keep notes of visitor numbers, particularly counts of parked cars at access points, usually when duties take them there, rather than on a planned sampling schedule. Some mathematical expansion factors are applied to the recorded observations to produce a use estimate.

3. Trail register data. Data from voluntary, unstaffed trail registers are summarized. Usually some expansion is made for nonregistration. However, registration behavior is usually not observed and an assumed rate is generally used. Often one expansion factor is applied to totals, rather than several separate factors applied to particular types of visitors with different registration rates, such as horseback riders and hikers, day-users and campers, and so on (Wenger and Gregersen 1964; Lucas and others 1971; Leatherberry and Lime 1981; Petersen 1985).

4. Wilderness permits. Permits are used where use is controlled; for example, camping in the backcountry of many major National Park's, all use of the Boundary Waters Canoe Area, and several wildernesses managed by the Forest Service in the southern Appalachians. Permits are also used in several wildernesses where use is unrestricted; for example, all National Forest wildernesses in California (only a few of which control use). Permits, in addition to their other uses, provide managers with recreational use data that are usually the most accurate of all use estimates. Sometimes adjustments are made for noncompliance and variation between planned and actual use (Lime and Lorence 1974; Kraushaar and others 1979; van Wagtendonk and Benedict 1980).

5. Trail traffic counters. Several kinds of automatic counters, such as pressure pads and infrared beam counters, are used to estimate numbers of visits (Leonard and others 1980), but estimates of visitor-days require other data on length of stay, either from trail registers or guesses, to multiply times visits.

Researchers' Use Estimation Techniques.—Researchers have used additional approaches that have been used infrequently by managers and also have studied the relation of actual use to data from trail registers and permits.

1. Direct observation. One such approach is personal observation as part of a formal systematic sampling plan. The sample is usually stratified by weekday/weekend, season, and perhaps access point or groups of accesses. This approach can produce estimates to any desired level of accuracy, but even for fairly modest accuracy, it usually requires considerable sampling intensity. Resulting high costs have limited usefulness of the method to managers (Lucas and others 1971; Leonard and others 1980).

2. Time-lapse photography. A movie camera is modified to expose one frame of film at a selected interval. The method has been used primarily to record river recreational use, and has been quite successful (Marnell 1977; Marnell and others 1978). This is because long stretches of rivers can often be photographed so that exposures evenly spaced at relatively long time intervals will not result in any parties going by unobserved. This is seldom the case on trails. There, exposure intervals close enough to record all visitors would exhaust film quickly, with most frames showing no visitors.

3. Cameras automatically triggered by traffic counters. A modified movie camera exposes a frame or two whenever a trail traffic counter, usually an infrared beam counter, is activated by passing visitors (or wildlife, including one grizzly bear on a Bob Marshall trail). The technology was developed originally by the Forest Service Equipment Development Center in Missoula, MT (DeLand 1976; Gasvoda 1978). It has been used in a number of research studies (Leonard and others 1980; Leatherberry and Lime 1981; Lucas and Kovalicky 1981; Petersen 1985). Film is not used unneccessarily when no visitors are there, and persons classifying recreational traffic by viewing the film do not have to search through hundreds of frames to find those showing visitors. Automatic cameras can be used to directly record use or measure trail register registration rates, which is discussed further below. This method has been used mainly on trails, but can be used on fairly narrow streams, where the traffic counter's maximum range of 90 to 120 feet is not exceeded.

More information is obtained than from traffic counters alone. Method of travel—for example, hiking or horseback—can be determined and length of stay—day-use or camper—can usually be identified from presence or absence of large backpacks or pack horses. Direction of travel is obvious. Usually party size can be determined.

Equipment costs are significant for traffic counters, cameras, and film editors or special projectors (Leonard and others 1980), and care in installation is important. But a nearly complete record of use near an access point usually is produced at total costs well below personal observation, and without the boredom or hardships of enduring all sorts of weather that would afflict an employee sitting on a log hour after hour.

Concerns for privacy are critical. The usual guidelines suggested by agency attorneys are to: use the system only to measure and classify recreational visitor traffic, place the camera far enough from passing visitors or adjust the focus so that 8-mm photo quality is not good enough to identify individuals, and destroy the film after it has been viewed and traffic tallied (Leonard and others 1980). Apparently these guidelines have been observed reasonably well because controversy has been very limited.

This is an effective and reasonably cost-efficient system that has been adopted by many wilderness managers.

4. Formal systematic observation of visitor registration behavior. As early as 1961, researchers began studying visitors' responses to voluntary, unstaffed trail registers (Wenger 1964). The concept, still applicable today, was

that trail register data provide a base that could be adjusted by a mathematical operation to estimate total use if visitor registration rates were known.

Actual registration behavior was determined in several ways. Several early studies conducted brief interviews to collect the same type of information called for on the trail register, with interviews conducted far enough beyond the trail register to be out of sight of parties at the register and avoid influencing behavior (Wenger 1964; James and Schreuder 1971; Lucas and others 1971). Observation with binoculars was used in one study (Thorsell 1968). Pressure-plate traffic counters were tried (Lucas and others 1971; Leonard and others 1980), as were prototype ultrasonic traffic counters (Lucas and others 1971) and infrared beam traffic counters (James and Schreuder 1971). The most common technique in recent years, and the most effective, has been the movie camera triggered by an infrared beam trail traffic counter (Leonard and others 1980; Leatherberry and Lime 1981; Lucas and Kovalicky 1981; Lucas 1983; Petersen 1985).

A number of studies of registration behavior produced variable results (table 15). Overall registration rates in different wildernesses and other wild, roadless, backcountry areas, with various types of registration stations, ranged from a low of 18 percent in the Idaho Primitive Area, to a high of 89 percent in the Rawah Wilderness in Colorado.

The study results in table 15 suggest, at first glance, that registration rates have declined irregularly over the years. However, there may be little or no time effect. What probably accounts for most of this variation is the relative proportions of different types of use occurring in each study area. As table 15 shows clearly, there are large differences in registration rates among different types of visitors. Specific registration rates vary in response to local differences in registration stations and basic characteristics of user populations, but the pattern of relative registration rates is consistent to a degree that is rare in recreation research. Hikers always register at substantially higher rates than horse users. Campers always have higher registration rates than day-users. When method of travel and length of stay are considered in combination, camping hikers (backpackers) lead the list, followed by day hikers, and camping horse users; day horse users always have very low, often 0 percent, registration. The only test of self-issued mandatory permits (Lucas and Kovalicky 1981) had a slightly different order due to high registration by camping horse users. (Mandatory self-issued permits, used a few places primarily in the West, differ from trail registers in that they are mandatory rather than voluntary. A copy of the permit is supposed to be carried by the visitor for possible field checking, while another copy is deposited at the permit-issuing station.) Hunters, partly reflecting the travel-stay relationship, have low rates, much lower than nonhunters, and partially as a result, fall registration rates are lower than summer rates, with the one exception of the only study of self-issued permits (Lucas and Kovalicky 1981). Larger parties, at least up to moderately large groups, register at a higher rate than small parties, and single visitors have the lowest rate of all.

Table 15.—Reported percentage registration rates from studies of visitors' responses to trail registers

Wilderness area (State)	Year	Visitor types							
		All visitors	Hiker	Horse users	Day-use	Camper	Day hiker	Day horse users	Camping hiker
Three Sisters (OR), Mountain Lakes (OR)	1961-62	74	79	40	78	81	78	—	81
Mission Mountains (MT)	1968	65	66	44	63	74	—	—	—
Banff NP (AB)	1968	35	—	—	—	—	—	—	—
Rawah (CO)	1970	89	—	—	—	—	—	—	—
Selway-Bitterroot (ID & MT)	1974	28	31	11	19	49	—	—	—
Idaho Primitive Area (ID)	1975	18	—	—	—	—	—	—	—
	1976	35	—	—	—	—	—	—	—
	1977	23	—	—	—	—	—	—	—
Sawtooth (ID)	1975	78	—	33	—	—	85	—	87
Waterton Lakes NP (AB)	1976	78	78	64	—	—	—	—	—
Spanish Peaks (MT) (Spanish Creek, July-Aug. only)	1977	50	58	14	32	74	40	0	78
Spanish Peaks (MT) (self-issued mandatory permits)	1978	53	55	35	45	72	51	25	72
McCormick Forest (MI)	1978-79	66	[1]66	—	—	—	—	—	—
Bob Marshall (MT) (7 trails)	1981	20	39	7	18	20	24	0	47
Bob Marshall (MT)	1982								
Conventional trail register, at trailhead		32	34	8	21	54	23	0	57
Newly designed register, 1 to 3 miles up trail		69	80	50	55	74	65	14	88

[1] All visitors to the McCormick Forest were hikers.

Table 15.—(Con.)

Visitor types									
Camping horse users	Summer	Fall	One-person parties	Small groups (2/2-3)	Medium groups (3-4/5-6)	Large groups (6-7 or more)	Weekday	Weekend	Source
—	—	—	37	73	82	84	72	76	Wenger and Gregersen 1964
—	74	41	55	63	72	66	72	62	Lucas and others 1971
—	—	—	—	—	—	—	—	—	Thorsell 1968
—	—	—	—	—	—	—	—	—	James and Schreuder 1972
—	—	—	10	35		17	30	26	Lucas 1975
—	—	—	—	—	—	—	—	—	Personal communications, Dodds
—	50	21	—	—	—	—	—	—	
—	35	15	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	Mullins 1975
—	—	—	—	—	—	—	—	—	Scotter 1981
50	—	—	—	—	—	—	—	—	Lucas (unpublished); Lucas and Kovalicky 1981
70	53	53	41	57		60	—	—	Lucas and Kovalicky 1981
—	72	57	60		84	100	—	—	Leatherberry and Lime 1981
7	35	5	—	—	—	—	—	—	Lucas 1983
									Petersen 1985
20	—	—	—	—	—	—	—	—	
56	—	—	—	—	—	—	—	—	

The areas where high registration rates have been reported are primarily backpacking wildernesses, with few horse users. These include Three Sisters, Mountain Lakes, Mission Mountains, Rawah, and Sawtooth Wildernesses, Waterton Lakes National Park, and McCormick Forest (table 15). The lowest overall registration rate for any of these areas was 65 percent. Areas with substantial horse and hunter use include the Selway-Bitterroot and Bob Marshall Wildernesses and the Idaho and Spanish Peaks Primitive Areas. At these areas, registration rates ranged from 18 to 50 percent, with most at the lower end. The only exceptions were the self-issued permit test in the Spanish Peaks (Lucas and Kovalicky 1981) (53 percent), and the experimental registration station tested by Petersen (1985) in the Bob Marshall (69 percent).

Locating trail registers some distance up a trail, rather than near the trailhead, appeared to result in higher registration rates in studies in the Sawtooth Wilderness (Mullins 1975) and the Spanish Peaks Primitive Area (Lucas and Kovalicky 1981). Petersen (1985) tested location in a controlled experiment. Two types of trail registration stations were moved from trailheads several miles up the trail and back on a random basis. Her results showed conclusively that up-trail locations produced substantially higher registration rates than trailhead locations. When the new station design was placed up the trail, registration rates more than doubled from rates at the old standard station at the trailhead.

Trail register messages also influence visitor registration behavior. Scotter (1981) and Lucas and others (1971) indicated that lack of understanding of the reasons for registration was a major reason for nonregistration. Petersen (1985) designed a sign (fig. 2) that presented three reasons very briefly, and visitors responded with higher registration rates. (The standard sign, which gave only a very general reason, read, "This will help us meet your needs in the area.") Camping horse users, in particular—usually a difficult group to get to register—more than doubled their registration rate.

Mathematical approaches to generating use estimates from trail register data suggest that simple procedures, regression or ratio estimation, work just as well as more complex techniques (James and Schreuder 1971, 1972; Lucas and others 1971).

5. Road traffic checks. This technique, sometimes called a "cordon line," involves gathering data on visitor traffic on access roads to a wilderness or similar area, through brief roadside interviews, and using these data as a base for estimates of total use and its characteristics. It is most practical for areas with only a limited number of access roads, especially roads that dead-end at the wilderness, and carry limited nonrecreational traffic. Sometimes road traffic counters have been used to aid in the expansion of interview data (Lucas 1964a). In other cases, traffic counters were not used, and interviews at roadblocks were used to estimate amount and type of use (Cushwa and others 1965). The technique is effective, but it is a major undertaking and costs can be substantial. This approach has not been used by managers.

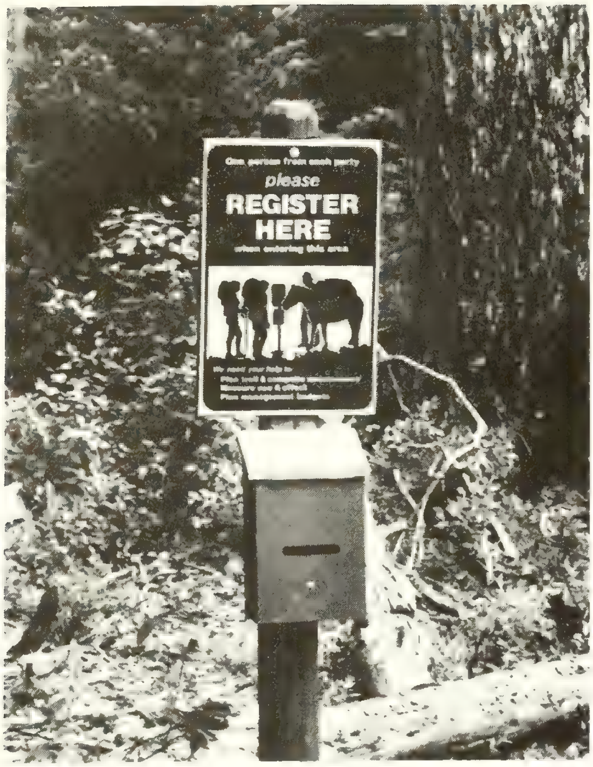


Figure 2.—Experimental trail register design (from Petersen 1985).

Trend Analysis

Studies of trends in wilderness use and user characteristics have been scarce. Because of the problems described above with basic use data of low accuracy, lack of comparability between wilderness-managing agencies, and discontinuities over time, analyses of trends in amount of wilderness recreation use have been hampered.

Before passage of the Wilderness Act in 1964, the only established wilderness was in National Forests. The National Park Service and Fish and Wildlife Service had some lands designated as wilderness later, and the Bureau of Land Management much later after passage of the Federal Land Policy and Management Act in 1976. However, other than the Forest Service, none of the agencies have reported recreational use specifically for wilderness units. Thus, the data on use of National Forest wilderness are the main available record of recreational use and trends. Data began in 1946 and are available for every year thereafter, although units of measure changed from 1964 to 1965, and number of visits were not reported after 1969. Reported figures show some erratic ups and downs (table 16), and visits and man-days do not always parallel each other as one would expect unless lengths-of-stay were fluctuating sharply. The first years after the switch to 12-hour recreation visitor-days show curious changes. Average length of stay in 1966 was 3.4 12-hour days, but in 1967 the average dropped to 2.3. These shifts back and forth raise some concerns about accuracy, but, as the saying goes, "It's the only game in town." Taking the figures at face value, the rates of increase were highest in the 1940's and 1950's, with double-digit increases most years; slowed somewhat in the 1960's and 1970's, with single-digits most common; and decreases for several years. In the 1980's, decreases became more common than increases, despite additions to the wilderness system.

National Parks have reported overnight stays in backcountry, whether classified as wilderness or not, since 1971. Much of this use is essentially wilderness use, and most of it is in areas that may eventually become official wilderness. The trend for the major wilderness-type parks was steadily upward to a peak in 1976 (table 17). Since 1976, use has declined about one-third, and, except for a rebound in 1980, the downward trend has been steady.

Reasons for these declines are not clear. The trends for National Park and National Forest use (table 1) are rather different; since 1976, even the direction of change has been different in all but 2 years—1982 and 1983. If broad social-economic changes were causing decreased recreational use of wilderness-type lands, one would expect more parallel changes. Additions to National Forest wilderness could cause some differences in trends, but most of the areas were added in 1984 and are not reflected in the data in table 1. Large Alaskan areas were added in 1980, but their use was light, only 3 to 4 percent of all National Forest wilderness use most years.

McCool (1985) examined the hypothesis that wilderness designation causes a spurt in recreational use, "a kiss of death" of sorts. He had use data for years before the Rattlesnake Wilderness, MT, was designated—the only case where such data existed—as well as after designation. He found little change, and concluded that the designation effect is not inevitable.

Petersen (1981) approached the designation effect by tracing rates of change in reported use for newly designated National Forest wildernesses to determine if new areas showed more rapid increases than long-established areas. Most did, but the effects were variable and not as large as common speculation would have suggested. Studies of trends in use and user characteristics are almost as scarce, and most include only a few characteristics and rather short time periods.

Changes in numbers of visitors for the main types of use in the Boundary Waters Canoe Area from 1961 to 1966 were studied by Lucas (1967). Total use increased 19 percent, but paddling canoeists and boat campers both increased about 55 percent. Use in 1966 was more evenly distributed among access points than in 1961. More visitors came from outside Minnesota, parties became slightly larger, and stays became shorter over the 5 years.

Use of the Allagash River, ME, more than doubled from 1966 to 1975, parties became smaller, and stays shorter (Cieslinski 1980). Visitor surveys in 1973 and 1975 included data on only eight variables, with little change except a decline in the number of large parties.

Use of the Rattlesnake Wilderness grew slightly from 1977 to 1981, and groups grew smaller (Corti and others 1982). Limited visitor surveys in 1978 and 1981 showed few changes, except a tendency for 1981 visitors to have less previous experience in the area than 1978 visitors.

Table 16.—Reported annual total use of National Forest wilderness and primitive areas, in thousands, and percent change between years

	Man-days		Visits		Recreation visitor days	
Year[1]	Thousands	Percent change	Thousands	Percent change	Thousands	Percent change
1946	406	—	144			
1947	499	+23	194	+35		
1948	657	+32	213	+10		
1949	761	+16	244	+15		
1950	787	+3	246	+8		
1951	809	+15	312	+27		
1952	953	+18	387	+24		
1953	1,317	+38	408	+5		
1954	1,047	−21	396	−3		
1955	1,175	+12	462	+17		
1956	1,364	+16	448	−3		
1957	1,654	+21	535	+19		
1958	1,685	+2	556	+4		
1959	1,950	+16	562	+1		
1960	1,903	−2	614	+9		
1961	2,047	+8	757	+23		
1962	2,136	+4	815	+8		
1963	2,752	+29	937	+15		
1964	2,872	+4	957	+2		
1965			NA	—	4,522	—
1966			1,392	[2]+45	4,791	+6
1967			2,029	+46	4,690	−2
1968			2,028	0	5,056	+8
1969			[3]2,028	0	5,072	0
1970					5,843	+15
1971					6,691	+15
1972					6,459	−3
1973					6,682	+3
1974					6,743	+1
1975					7,513	+11
1976					7,106	−5
1977					8,008	+13
1978					8,620	+8
1979					9,605	+11
1980					9,268	−4
1981					11,417	+23
1982					11,158	−2
1983					9,909	−11
1984					10,209	+3

[1] Years are calendar years through 1976 and fiscal years (October through September) thereafter.
[2] Percent change for a 2-year period.
[3] Reported visit totals for 1968 and 1969 were identical; this is not an error.

Use of Yosemite National Park's backcountry rose rapidly to 1975, but declined from then to 1979 (van Wagtendonk 1981). (Park Service annual use reports show backcountry camping has since risen and declined again.) Two separate surveys only 2 years apart (1973 and 1975-76) showed little change in age, education, income, party size, and length of stay. There were more female visitors in the latter survey, and use was a little more evenly distributed over the season and over the trail system.

In 1970 and 1982, comprehensive visitor surveys were carried out in the Bob Marshall Wilderness complex, which includes the Bob Marshall, Great Bear, and Scapegoat Wildernesses in Montana (Lucas 1985b). The major change in use characteristics was a shift from predominantly horse use in 1970 to mainly backpacker use in 1982. Both horse and hiker use increased, but hiker use grew much faster. Many other changes seemed to stem from this basic shift: shorter stays, smaller parties, a smaller proportion of visits with outfitters, some shift in activities from more consumptive to more contemplative, more summer and less fall use, and less dependence on wood fires. Other changes in use characteristics were: less weekend peaking and less concentrated use. These changes seemed to imply lower potential for impacts to resources on a per-party basis.

Most visitor characteristics remained about the same or changed only moderately from 1970 to 1982. The essentially unchanged characteristics included urban/rural residence, type of social group, age distribution, high levels of overall wilderness experience, and club membership. Modest changes from 1970 to 1982 included more visitors

Table 17.—Reported total annual use of wilderness and backcountry in 17 major National Parks[1]

	Overnight stays	
Year	Thousands	Percent change
1971	712	
1972	857	+20
1973	910	+6
1974	1,027	+13
1975	1,115	+9
1976	1,231	+10
1977	1,098	−11
1978	904	−18
1979	902	0
1980	996	+10
1981	968	−3
1982	881	−9
1983	865	−2
1984	833	−3

[1] Includes data from Big Bend, Denali (Mt. McKinley), Everglades, Glacier, Grand Canyon, Grand Teton, Great Smoky Mountains, Kings Canyon, Mount Rainier, North Cascades, Olympic, Rocky Mountain, Sequoia, Shenandoah, Voyageurs, Yellowstone, and Yosemite National Parks.

from out of State, more women, higher educational levels, more visitors in professional and technical occupations, and less previous experience in the Bob Marshall Wilderness complex, especially for backpackers. These changes also reflect the shift to more backpacker use. Many changes in visitor characteristics seem to point to slower future growth in use.

Burde and Curran (1986) studied changes in use, users, and attitudes in Great Smoky Mountains National Park's backcountry from 1973 to 1983. Visitors in 1983 were older, more experienced, more often with peer groups of friends than family groups, and in smaller groups. Slightly more women visited the backcountry in 1983, and average trip length was about the same across the two study periods.

Projections

Projections of wilderness recreational use have been limited by poor and noncomparable basic use data, and also by scanty knowledge of the relationship of wilderness use to causal factors.

Probably the earliest projection of wilderness use was made as part of the Forest Service National Forest Recreation Survey project in 1961 (USDA-FS 1961). An unpublished projection of National Forest wilderness use foresaw a tripling of man-days by 1976 and more than eightfold growth by the year 2000 (table 18). This is a little more than a 5 percent average annual rate of increase. The actual reported figure for 1976 was 7,105,600 12-hour visitor-days, compared to 5,804,000 man-days—a different unit of measure. There is no way to convert from one unit to the other with any precision because fractional man-days had highly variable definitions in visitor hours, but a suggested rule of thumb is 1.5 visitor-days per man-day (Hendee and others 1978, p. 289). Using 1.5 as a rough conversion factor suggests projected 1976 use of about 8,700,000 visitor-days, or about 22 percent more than was actually reported.

Table 18.—National Forest wilderness use projections in thousands of man-days and percentage change projected

	1959 (actual)	1976	Percent change	2000	Percent change
National Forest Recreation Survey (1961)	[1]1,950	5,804	+198	16,183	+730
Outdoor Recreation Resources Review Commission (1962)	[1]1,399	4,948	+254	12,053	+762

[1] The National Forest Recreation Survey included data for all areas; the ORRRC study excluded areas smaller than 100,000, then called "Wild Areas."

The projection technique was based on simple assumptions, with no supporting research (there was no recreation research to speak of in 1959). Per capita use was projected by multiplying the ratio of projected per capita real income in the target year to its level in the base year times similar ratios for leisure and miles traveled. The result was multiplied by projected population. This procedure illustrates another problem in recreation projections; the procedure requires projections of population, income, leisure, and travel, variables that are probably as hard to project as recreation use itself. The "independent variables" also are obviously not independent of one another.

At almost the same time, wilderness use was projected as part of the Outdoor Recreation Resources Review Commission (ORRRC 1962) studies. They also worked only with National Forest data (no wildernesses were managed by any other agency before 1964), and also used man-days. These projected rates of increase were similar to those of the Forest Service study (USDA-FS 1961) (table 16). This is surprising because the projection procedures were quite different. The ORRRC projections were based only on income and population. Per capita wilderness use was related to income with a regression model, using National Forest-reported wilderness and primitive area man-days from 1947 to 1959. These predictions of per capita use were multiplied by projected population.

There appears to have been almost a 20-year gap before other wilderness use projections were developed in response to Resource Planning Act (RPA) requirements. Three projection studies were published in 1982 or 1983, all of them using more advanced statistical techniques than the early studies. Jungst and Countryman (1982) developed several models. One approach used time-series cross-sectional regression, with both supply and demand variables, with a resulting projected average annual rate of increase of 2.6 percent to the year 2020. The second approach used regression analysis, using supply, population, and lagged wilderness use (use in the previous year) as independent variables. This model projected an average annual rate of increase of 7.2 percent to the year 2020.

Hof and Kaiser (1983a, 1983b) did not project wilderness use itself, but included several activities that probably parallel wilderness use, particularly dispersed primitive camping. Their approach involved estimating per capita participation using a number of socioeconomic and supply variables in a regression model, and applying the equation using high, medium, and low projected values for the independent variables. Primitive camping was projected to increase from a 1977 base of 100 to 155, 205, or 311 by 2030 in the low, medium, and high scenarios. These indices translate to annual average rates of growth of less than 1 percent to a little over 2 percent.

A very different sort of time frame was used by Oliveira and others (1983) to project wilderness use a few days into the future (by projecting arrivals and departures). This was intended to determine available unused capacity for which permits could be issued in areas with use control programs.

It is clear that knowledge of wilderness use projections is very limited. About all the handful of studies agree on is an increase in future use, but at widely varying rates. None suggest the slowing or declines that have appeared in recent years.

ADOPTION OF RESEARCH BY MANAGERS

Successes

Many wilderness management plans for areas where use and users have been studied have applied these research data. Estimates of the amount and type of use have been used to evaluate "people pressure" and determine the need to modify or limit use. The same types of data have been used to decide on the need for developments, such as horse loading ramps or outhouses, at specific trailheads. Trail plans have used data on use distribution to set appropriate maintenance standards, evaluate possible changes in the trail network, and judge the potential for conflict between different types of use. Plans for areas that have not been studied have also been affected in general ways by improved knowledge of the typical characteristics of use and users.

The Limits of Acceptable Change (LAC) system has been developed to manage wilderness recreational carrying capacity (Stankey and others 1985; Lucas 1986). In the initial application of the LAC system to the Bob Marshall Wilderness complex in Montana, use pattern data were used to help define wilderness opportunity zones. Use data were applied in a similar way in the Maroon Bells-Snowmass Wilderness in Colorado. Use data were also employed as input to wilderness use simulation models to help establish encounter standards and select locations for monitoring encounters in the Maroon Bells-Snowmass Wilderness and the Desolation Wilderness (Shechter and Lucas 1978).

Information on amount of use and use distribution has generally shown that even the most heavily used wildernesses are lightly used during many times and in many places. Managers in some areas, such as Linville Gorge, have responded to this information by dropping overall area use limits, and instead have adopted weekend limits at high use times and an informational program to teach low-impact behavior.

Efforts in some areas to disperse or redistribute use have applied data showing existing uneven, concentrated use patterns to try to redistribute use and plan specific efforts. Sometimes the data on use patterns have been directly provided to visitors (Lime and Lucas 1977; Lucas 1981; Roggenbuck and Berrier 1982). Use pattern data have been applied to deciding when and where to station persons to make educational contacts. Data on visitors' home locations and membership in conservation and outdoor clubs have been used to choose target areas and audiences for education efforts. Finally, the high education levels of wilderness users have encouraged managers to turn to informational contacts to teach minimum-impact use practices.

Some regulations have drawn partly on use/user data. Limits on party size are the main example. Limits have been justified mainly from studies of social and ecological impact; and in the early 1970's some areas established limits at 12 to 15 persons per group. Use data have since shown that there are relatively few parties of this size, so relatively few users are affected. More recently, such party size regulations have not been adopted, not because large groups are now condoned, but because the restrictions are no longer necessary; there have been reductions in the size of visitor groups.

Basic use and user data have been essential for the relatively few trend and projection studies, which are potentially useful to management.

The basic trail register system, widely used, especially by the Forest Service, was developed by research (Wenger 1964).

Missed Opportunities

In general, available research results of use and user characteristics have been applied well by policymakers and managers. There are some cases, however, where application has lagged. Most notable among these are wilderness use estimation technology, implications of the large number of day-users of wilderness, access and trail routing, wilderness travel simulation technology, comprehensive application of information and education programs, and a comprehensive financial support program for professional wilderness management.

Although the development of wilderness use estimation methods has not been completed, available knowledge is not being used fully. Research has shown that location of trail use registration stations some distance up the trail produces much better response from visitors (Lucas and Kovalicky 1981; Petersen 1985), but trailhead locations continue to predominate, mainly because of convenience and associated lower costs. The necessity of determining registration rates to estimate use is obvious, but it seldom is actually done by managers. Cost is the major hindrance, although photographic monitoring equipment, which research helped develop, reduces costs considerably.

One of the most surprising and pervasive findings of use and user research is the large number of day-users in wilderness. These individuals seldom penetrate to the wilderness core and likely have relatively light ecological impacts. They do, however, cause congestion along the periphery and outer zones of wildernesses, and they may be neither seeking nor receiving wilderness-dependent experiences. If this is the case, managers might reduce wilderness impacts by developing additional day-hiking opportunities in areas outside wilderness and informing hikers of these opportunities. In some cases such opportunities already exist, and all that is needed is a better information system. Some managers, such as in Shining Rock Wilderness in North Carolina, have already adopted such a strategy, but the potential for more extensive use exists.

The distribution of use among access points and along trails is very uneven in many areas. At the same time, use is largely confined to trails. Access points and trail routes thus become powerful management tools. By altering trail system configuration (such as closing some trails, adding loop trails, or branching trails from major trail trunks) and improving or failing to maintain access routes, managers can largely influence how many people use various zones of wilderness. Again, this strategy has been used by management, but not as extensively as it might be.

As has already been noted, many wilderness managers, such as those in Eagle Cap Wilderness, OR, and Shining Rock Wilderness, NC, have recognized the high education levels of wilderness users and have implemented informational programs to disperse use or teach low-impact practices. However, few areas, even the Boundary Waters Canoe Area or Yellowstone National Park where successful pilot programs to redistribute use through information have been tested (Lime and Lucas 1977; Krumpe and Brown 1982), have continued these programs. Research suggests that success of such programs depends on the source of the information, amount of information given, the timing of message transfer, the channel used to communicate the information, actually getting the message to the target audience, and characteristics of the audience and the situation (Roggenbuck and Watson 1986). Available knowledge of such wilderness use and user characteristics as education levels, use patterns, activities, behavior, background experience, and knowledge could be used to better tailor messages to audiences. This tailoring process admittedly must be subtle, perhaps as much art as science.

Limited budgets are almost certainly the most frequent reason for any lags in the adoption of management programs suggested by use and user data. Developing a soundly funded program to manage wilderness is probably the biggest challenge of the next decade. A partial solution to the dilemma may be found in data on wilderness user characteristics. Wilderness users as a group have above-average incomes. Most could afford a modest wilderness use fee.

RESEARCH ISSUES AND FUTURE DIRECTIONS

Use Measurement Technology

It is apparent that many types of wilderness research are hampered by the poor quality of recreation use estimates. Projection and trend studies suffer severely, as has been pointed out, but so does research on impacts to the environment. Poor use data hinder skillful, professional management as well. Thus, we conclude that development of improved use measurement technology is still an important need.

Accurate techniques are available; the problem is lack of a cost-effective, accurate technique. Years ago, the scientists who did the most research on this topic (James and Schreuder 1971) said, "The authors believe that a satisfactory procedure is near at hand." That statement was probably true then and, unfortunately, it is still true almost 15 years later. The concerted research effort to close the gap never occurred.

Wilderness use measurement technology is not easy to develop, or it would have been done before now. However, it is a relatively "solvable" problem. If adequate resources were devoted to it for a reasonable time period, perhaps 5 years or so, the probability of solution would be high, probably higher than for almost any other significant problem (Shafer and Lucas 1979).

Coverage of Use/User Studies

Visitor surveys have been the most common approach to studies of wilderness use and users. They have become less common in recent years. We welcome the emphasis on research on relationships and processes, but there is also a need for careful descriptive research. The results are directly useful to managers and planners, and also help researchers in selecting appropriate study areas, designing sampling plans, and extending results to other similar situations. Repeat descriptions can yield cross-sectional trend analyses.

We feel that more site-specific comprehensive visitor surveys are needed. The National River Recreation Survey (Knopf and Lime 1984) could be a model. Standardized instruments are used on a wide variety of rivers, distributed fairly evenly across the country and managing agencies, with rigorous sampling plans.

Wilderness use and users are almost undescribed in some regions of the country—the Southwest, for example—and they have been described in only a few wildernesses in many areas, including California, which has more reported wilderness use than any other State. Except for the Boundary Waters Canoe Area Wilderness, wildernesses in the Midwest and South-Central regions are unstudied.

Some types of use have been little studied anywhere. Most wilderness surveys have concentrated on the main summer use season. Hunters and other fall visitors have been included in only a few studies, and none have focused on them. Winter snow-season use has been little studied. (The only winter use studies we found are by Gilbert [1980], Taylor and Mackoy [1980], Taylor and Spencer [1980], and Hammitt and Hughes [1984].)

Data for many areas that have been studied are over 20 years old. In the meantime, use has more than doubled, the environmental movement arose and peaked, and a new generation of people has become wilderness visitors. The validity for the mid-1980's of visitor profiles from surveys done in the 1960's is a major question.

Trends

More knowledge of trends in wilderness use and users is imperative for effective management. In fact, one of the main uses for improved recreational use measurement is identification of trends.

Similarly, user surveys, although useful in their own right, become much more valuable when trend information from repeat surveys or other sources is available to aid in interpretation. Managers can better evaluate a potential problem situation if, in addition to information on the current situation, they know if the particular case is improving, deteriorating, or stable. If groups are becoming smaller, for example, as they seem to be in many places, the need to institute party size limits is reduced. If visitors' reports of campsite solitude show fewer contacts with other campers, the need for additional actions by managers is far less than if the trend is toward higher contact levels, even though the current level of contacts is identical in both cases.

Stable or declining use suggests a need to reexamine some use controls. Most controls were instituted in a time of rapid growth and anticipated future growth. Managers were often trying to nip problems in the bud as much or more than solving existing problems. Some use rationing, and assigning of campsites, might be relaxed if use is dropping. For example, some National Parks with stringent visitor controls now report only half as much use as 8 or 10 years ago.

In addition to multiple cross-sectional survey data, other longitudinal approaches are needed. Following the changes in wilderness user behavior and experiences (and responses, attitudes, and preferences) of a sample of individuals over time, in a panel study, would tell us things about the dynamics of change that are only hinted at in multiple cross-section surveys. In particular, succession-displacement can only be studied with longitudinal research designs. This approach, effectively used by LaPage and Ragain (1971) in research on developed camping, can enrich our understanding of the processes of change. This approach would be especially useful for understanding the recent declines in use, and might suggest if the future is likely to feature declines, stability, or renewed growth.

Privacy, Consideration

Concern for the subjects of visitor research must be kept high. Wilderness visitors have been marvelously cooperative with researchers. They answer questions with sincerity and friendliness, and exceptions are so rare as to be notable. In 25 years of wilderness visitor research, one of us (Lucas) has encountered only two visitors who declined to provide information, and one of them was almost surely an unlicensed, illegal outfitter who, understandably, wanted to keep a low profile.

Further evidence of the good will of wilderness visitors is the extremely high rates of return of mail questionnaires, generally in the 80-percent and even 90-percent range. Wilderness visitors truly must be one of the very best special populations for social science research.

Beyond legal questions, particularly for photographic observation techniques, researchers owe these visitors all the consideration and sensitivity possible. Imposing on visitors' good will and interfering with an experience that is very important to most of them must be minimized. For example, interviews at campsites interrupt visitors (although researchers who have used this technique report they sensed little resentment) (Roberts this volume), and only a few types of studies with objectives that require data on visitor evaluations of specific, onsite conditions are appropriately approached onsite. Guarantees of confidentiality and anonymity must be strictly observed. Overstated promises are unethical.

Cameras used for observation are a powerful new tool with the potential for abuse. Their use must meticulously follow legal guidelines, but also be sensitive to people's concerns. A trail register is essentially a public place; a campsite or a wilderness swimming hole is not, and photographic observation should be limited to public places. It seems like a desirable courtesy to attach a small, simple sign to cameras and trail traffic counters explaining briefly what they are and what their purpose is, and including a phone number. This would ease curiosity or puzzlement by the few visitors who do detect equipment. Leatherberry and Lime (1981) did this, as did Petersen in her 1985 study.

Sampling Approaches

Visitor studies must be based on rigorous, scientifically valid sampling systems. Convenience samples, with undefined probabilities for sampling elements (individuals or groups), undefined populations, and unspecified sampling frames are not justified now, if they ever were. Enough is known about the difficult sampling situation to design valid approaches. Costs may be higher and, as a result, samples may be smaller, but, in social science, a large sample never can compensate for poor sample quality. Most field samples are cluster samples, and this needs to be recognized. Pretending a cluster sample is a simple random sample is common, but it almost always results in overestimates of the precision of estimates—in other words, calculated confidence intervals are misleadingly narrow.

Restrictions on Survey Research

Asking people for information about their use of wilderness and about themselves needs to be done with care. As discussed above, most wilderness visitors are very cooperative and welcome the chance to tell researchers about something that is near and dear to their hearts. However, asking poorly worded questions, gathering data not related to important study objectives, or gathering information with an inadequate sampling plan can result in a waste of respondents' time and effort. Very poor questions can even be embarrassing.

Therefore, review and control procedures are justified. Universities have committees for the protection of human subjects that review and approve proposed studies in social science, psychology, and medicine. Researchers who are Federal employees, or who are supported by Federal agencies, must obtain approval from the Office of Management and Budget (OMB) for any collection of information from 10 or more people. This requirement began with the Federal Reports Act back in the 1940's, and was made more stringent in the 1980 Paperwork Reduction Act. The major concern motivating the legislation was the heavy burden imposed on businesses and local governments to provide information for regulatory and taxation purposes or to qualify for some benefit such as cost-sharing. Horror stories abound of several agencies independently asking for similar information, one this month, another next month, but in sufficiently different ways that the same answers could not be used for all of the forms. Claims were common that information was requested that the agency did not really need or use. Companies claimed they had to hire extra accountants to fill out complex forms, which they were almost always legally required to do.

It is a long step from legally required business forms affecting numerous firms to small-scale, voluntary surveys of wilderness visitors. The common OMB term "respondent burden" hardly seems applicable to the wilderness visitors who are almost always willing and often eager to answer questions.

The problem is not the need for a review and approval process. We agree this is necessary for quality control to protect the public, the taxpayers, and also responsible, qualified scientists from poorly done survey research. The difficulty is the time required and the uncertainty of the process. To obtain approval, study planning now needs to start about 18 months before fieldwork is to begin. Scientists should submit the questionnaire, study plan, and extensive, detailed question-by-question justification at least 6 months before data gathering is planned to start. This submission is handicapped, how severely is unclear, if the study has not previously been included in the annual "Information Collection Budget," which requires preplanning almost a year before actually seeking OMB approval, and thus results in the total lead time of about 18 months cited above. Approval generally is perceived as a somewhat chancy "win some-lose some" proposition, although scientists have usually eventually received approval.

The effects of this slow, cumbersome approach are several: (1) a lot of work for someone at OMB, with little significant public benefit; (2) inability of researchers to respond quickly to emerging problems, managers' concerns, new scientific concepts, or follow up promptly on results of earlier studies; and (3) less chance for the public to express its desires and concerns. No other type of natural resource research must face delays such as those imposed by this formidable barrier. The result is that less wilderness visitor research is done. Some studies have been designed to use research techniques other than questionnaires to avoid the lengthy struggle, even though the study might have been strengthened if survey research methods had been included. We suspect some problems have been chosen for research because they could be studied without needing OMB approval for questionnaires.

Wilderness managers who might want to monitor key elements of visitor use to implement plans, judge their effectiveness, and guide their modification are stymied if they follow the law strictly. Monitoring levels of solitude, visitor conflicts, or visitor evaluations of changing recreational impacts has generally required specific approval for time and place of use of questionnaires, and busy managers have not had the time and energy to seek approval for monitoring that could not begin until the next year or, more likely, the year after next. Without systematic monitoring, they must make do with hunches and impressions. There are too few researchers to be able to do the monitoring for them (and researchers have other duties), and many managers have felt unable to do the monitoring themselves.

It would seem to be in everyone's interest (OMB officials, researchers, wilderness managers, the public, and taxpayers) if a simpler, quicker review process could be developed. One possibility might be limited delegation of authority from OMB to Federal agencies doing wilderness visitor research. In the Forest Service research branch, for example, the typical recreation and wilderness research scientist has a Ph.D. with social science training and 15 to 20 years of experience in research. Perhaps several of these scientists could be assigned the duty of serving as a peer review board for studies proposed by Forest Service scientists and their university cooperators.

This would require OMB delegation, which could be limited to voluntary interviews or questionnaires involving less than 1,000 respondents. Similar limited approval for wilderness monitoring by managers could be arranged. The risks from such an arrangement seem minimal and the potential benefits great.

Household Survey Need

Most research on wilderness use and users has been carried out onsite, with current visitors to a particular wilderness. Very few studies have involved the general public, or household studies. One reason is that, for all the difficulties of onsite sampling, general population studies focused on wilderness use are probably even more difficult, because wilderness users are a minority in most populations.

Nevertheless, many types of important questions cannot be answered just by onsite studies. Former visitors who have stopped coming to an area will be omitted, of course, and their reasons will remain unknown. Changing health, declining interest, or dissatisfaction with area conditions or with management actions may be involved, but we will never know if we rely on onsite surveys. This seems critical to explaining the surprising recent declines in use. What substitutes, if any, former visitors have found will not be known, either. Some of these questions could be addressed with longitudinal studies as well as general population surveys.

Similarly, potential visitors and the reasons that have kept them from becoming active visitors cannot be studied onsite, nor with longitudinal studies. Only general population surveys will reach this subpopulation. Other subjects, such as wilderness values and benefits to nonvisitors, can also only be studied in this way.

User Knowledge Research

There is a great need for wilderness use and user research to focus on visitors' knowledge of low-impact wilderness practices. Agreement must be reached through empirical research on what the ideal minimum-impact behaviors are. For example, some wilderness areas now recommend use dispersal to minimize impacts; others recommend use concentration. Some leave all firerings, some destroy most but leave one at each campsite, and some destroy all. Different methods are recommended to adequately dispose of human wastes. Once acceptable practices are selected, procedures must be developed to teach and measure knowledge of these practices. More information is needed on the relationship between knowledge of low-impact practices and actual behavior in wilderness. Finally, high-impact wilderness user groups must be identified, and reasons for their impacting behavior determined. We need to know if their impacts can be reduced through educational efforts, or if their impacts are the inevitable result of intrinsic use and user characteristics.

SUMMARY OF WILDERNESS USE AND USER RESEARCH

Any summary of wilderness use and users, trends, and projections must be prefaced by an acknowledgment of the lack of sufficient and system-wide research. Most wilderness use and user research has occurred in the Rockies and the Boundary Waters Canoe Area, with limited additional work in California, New England, and the Southeast. The Southwest, the Deep South, the Midwest except for the Boundary Waters Canoe Area, and even California have been little studied. In addition, most research has been conducted in mountainous and alpine wildernesses. As the Wilderness System has become more diversified to include a range of ecosystems, there is a need to study wilderness use and users in desert, swamp, and coastal plain wildernesses. Also, past research on use and users has focused primarily on National Forest wilderness, with limited coverage of National Park areas. There have been virtually no published studies on Fish and Wildlife Service and Bureau of Land Management-managed wilderness. Most research has only covered the summer and sometimes the fall season. We know little about spring and winter users, except that winter use is reported to be rising in many places. There is a critical need for more research because limited work suggests that wilderness use and users may differ more across seasons of the year than across time, areas, or regions (Hughes 1985). Finally, there have been almost no followup studies of the same areas across years. Such longitudinal studies are needed to determine trends and projections and understand causal factors.

While acknowledging that additional research to reduce knowledge gaps may provide more insights, we are struck by the similarities of wilderness use and especially users across areas, regions, and even year of study. Similarities are much more pronounced than differences. Indeed, the profile of wilderness users is much clearer than it is for other recreationists (Hendee and others 1978).

User Characteristics

There is a moderate overrepresentation of young adults among wilderness users. Under-35-year-olds are the most common. However, the 36-45 age group is also overrepresented in most areas, and both children and older adults visit wilderness in substantial numbers. Limited research suggests that the age structure of users is not changing through time.

Males are the big majority among wilderness users, usually from 65 to 85 percent of all visitors. Horse users are more typically male; hikers somewhat more likely to be female. Trends suggest an increasing use of wilderness by females. Wilderness is certainly not the absolute domain of men.

The most distinguishing feature of wilderness users is their high education. Everywhere wilderness users have much higher education than the general population for the States where they reside. For most areas, the percentage of wilderness users who have attended or are attending graduate school is larger than the percentage of the U.S. population that goes to college. Recent studies also show that education levels of wilderness visitors are even higher now than in the past.

Apparently there is more variation in the occupations of wilderness users across areas than for most other user characteristics. Generally, most users are professional and technical workers, followed by students. Housewives and clerical, sales, and service workers are the most underrepresented. Exceptions to this profile are large, western, horse-oriented wildernesses and scattered areas where local, rural users are common. Farmers, ranchers, and blue collar workers are more prevalent in these areas. Still, the typical user is a professional, and trends suggest that this will be even more the case in the future.

As a group, wilderness users have somewhat above-average incomes. For most areas, however, wilderness visitors could not be classified as wealthy. Most eastern area and California users have incomes well above the national average, but they appear to reflect the generally higher incomes of the residents of these States. The users of a few areas with considerable horse and outfitting use or airplane access apparently do have unusually high incomes. Research indicates that high incomes are not needed to enjoy most wildernesses. The typical visitor resides near the wilderness area, and costs per day to use and enjoy wildernesses are low.

Typically most wilderness users reside in the State where the area is located, and indeed most come from the region of the State that includes the wilderness. Thus, from the standpoint of recreation, most areas have a local or regional clientele. Wilderness areas in the East appear to diverge somewhat from this tendency. There, more visitors are from out of State. This likely reflects the small size of many eastern States, the scarcity of wilderness resources, and the high demand for wilderness experiences.

Most wilderness visitors are urban, but so, too, is the U.S. population. In many areas the proportion of urban to rural visitors is about equal to the proportion found in the State where the wilderness is located. This suggests that the overrepresentation of urbanites in wilderness may not be as great as some have suggested. In many areas the urban users had a predominantly rural upbringing, but this tendency was less strong among eastern area users. The proportion of urban to rural residents within wilderness appears quite stable for those few areas that have been studied in both the 1970's and 1980's.

Membership in wilderness, conservation, and outdoor clubs is generally low among wilderness users, usually below 35 percent. Exceptions appear to be some eastern areas with a highly urban clientele. Different kinds of users often belong to different types of organizations. Hunters and horse users more often join local clubs such as rod and gun clubs, while hikers have a tendency to belong to larger national conservation organizations.

Most wilderness users have considerable previous experience in wilderness. For most areas, 60 to 90 percent of the users have previously been to wilderness or backcountry areas, and about half have been to the study area before. Limited evidence suggests that visitors to recently established areas have less previous experience in the area. This suggests that wilderness designation does attract new clientele. Also, most wilderness users make multiple visits to wildernesses each year.

The most common group type in wilderness is the family—either the family alone or the family with friends. Such groups generally make up the majority of all groups, and limited research suggests their numbers are increasing. Groups of friends are typically the second most numerous. Organized groups such as Scouts or church groups usually comprise fewer than 10 percent of all parties.

Use Patterns

Distribution of wilderness use is very uneven through time, across areas, and within areas. Weekend peaking of use is severe, especially in western wilderness areas close to population centers. Peaking seems even more prevalent among winter wilderness users. On the other hand, the weekly pattern of use seems more evenly distributed among eastern areas, and recent studies show less weekend peaking than did earlier research.

Summer is the high season of use most places, but the ratio of summer to off-season use varies a great deal by area. Some areas have peaks of use of short duration during the fall hunting season, and October is a high-use month because of fall color in some eastern areas. Spring is a high-use time in a few low-elevation areas in the Southwest and southern California. Finally, while winter is typically a very low use period, use during this time appears to be increasing.

Use is also extremely variable among the many areas of the Wilderness System. A few areas often account for a third or more of an entire agency's wilderness visitation. Those near major population centers, such as, those in the southern Appalachians, New England, Minnesota, and California, are typically the most heavily used, but location does not explain all the variation. Some swampy wildernesses in the Southeast are lightly used, and several of the recently established eastern areas have little use. Such absence of use may be due to the lack of special attractions, absence of trail or travel routes, or lack of knowledge of the areas.

Use is also concentrated at a few entry points almost everywhere. Typically about a third of an area's trailheads account for about 80 percent of all use. Winter use appears even more concentrated, but summer use of eastern areas appears somewhat less concentrated. Some evidence suggests that dispersal of summer use to more trailheads is currently taking place. Cross-country travel—travel for considerable distances off trails—is low everywhere, but lower in the Northern Rockies than in mountain areas in California. Use of trails within areas is highly variable, and appears to be affected by trailhead location relative to population centers, ease of road access to the trailhead, trail system configuration, distance from the trailhead to the wilderness, and location of area attractions. Campsites tend to be located near water, and while campsite use is very uneven, it tends to be less so than use of trail segments.

Party size is small, averaging about four individuals in National Forest areas and two to three persons in National Park areas. Lone individuals are rare everywhere, but are about twice as common in National Park backcountry (10 to 15 percent of all groups) as in National Forest wilderness (where they typically make up from 5 to 10 percent). Parties of 10 or more accounted for 5 to 10 percent of use almost everywhere. Also, group size appears to be getting smaller through time.

Hiking is the primary method of travel everywhere except for such water areas as the Boundary Waters Canoe Area and for a few horse-oriented areas such as the Bob Marshall. There is almost no horse use in eastern wilderness areas; and even in western areas, the trend is away from horse use and toward backpacking use. Indeed, the biggest change that Lucas (1985b) found between the 1970 and 1982 use patterns among three western wilderness areas was a shift in proportions of total use away from horse use and toward hiking.

Correlated with the decline in the proportion of wilderness visitors who use horses is the general decline in the proportion of visitors who employ outfitters. Most areas studied have less than 1 percent of their visits outfitted. Only the Bob Marshall and the Great Bear Wildernesses have sizable numbers of outfitted parties, but the Bob Marshall Wilderness complex dropped from 35 percent outfitted groups to 17 percent from 1970 to 1982. Outfitting levels are quite high on some wilderness whitewater rivers, and also for a few large western wildernesses during the fall hunting season.

Length of stay of wilderness trips is short and getting shorter. Most areas have average lengths of stay of about 2 to 3 days. Exceptions are longer trips in the BWCA, the Bob Marshall, the Great Bear, and summer users in the backcountry of the Great Smoky Mountains National Park. In some areas 50 percent of all use is day-use, but this is highly variable. Trips of a week or more are rare everywhere, and distance traveled in wilderness is typically short. Horse trips tend to be longer than hiking trips. Winter use is generally shorter in time and distance than summer use, and length of stay is highly variable among eastern areas.

Finally, most wilderness users engage in multiple activities in wilderness. Generally, hiking, fishing, and photography are the most frequent activities. Following these in importance are nature study and swimming. Certain wilderness activity packages are common to different wilderness areas. The most common activity package includes hiking, fishing, swimming, and nature study, but low hunting and horse use. Desolation Wilderness is a prototype of this wilderness type. At the other extreme are areas such as the Bob Marshall and the Great Bear that have high horse use, hunting, and photography, but low hiking, nature study, and swimming. Limited trend data suggest that such consumptive uses of wilderness as hunting and fishing are declining in proportion to total use; the more contemplative activities are increasing.

Trends

The small amount of research on trends provides little thoroughly supported knowledge. The effect of regional differences and variations among individual wildernesses may confound trends over time, and there are not enough studies of different types of wildernesses to disentangle geographical and temporal effects. However, some similar results have emerged that can be cautiously considered as relatively well supported.

First, the rate of increase of wilderness recreation use seems to be slowing down. There are indications that use may be leveling off, and maybe even dropping. In several places, National Park backcountry use seems to have peaked in the mid-1970's (van Wagtendonk and Benedict 1980), and National Forest wilderness use appears to have possibly peaked in the early 1980's (table 1).

The "designation effect"—the idea that labeling an area as wilderness stimulates use markedly—is often mentioned, but its significance is an unsettled issue. There is some evidence for such an effect, although probably not as strong as some might expect (Petersen 1981), and other evidence that the effect is certainly not inevitable (McCool 1985). Perhaps the force of designation is diluted because the number of wildernesses has grown so large—over 450—and so many new areas have been added recently —162 new National Forest wildernesses in 1984 alone, as well as other new wildernesses in the other wilderness-managing agencies. Any new area is likely to be publicized less and compete for visitation with more areas than was the case earlier.

A number of trends in the characteristics of wilderness use and users have been reported in most of the few trend studies. Use seems to be spreading out more (Lucas 1967, 1985b; van Wagtendonk 1981); stays most places are becoming shorter (Lucas 1967, 1985b; Cieslinski 1980) but were unchanged in Great Smoky Mountains National Park (Burde and Curran 1986). More visitors are coming from farther away (Lucas 1964b, 1985b); parties are becoming smaller (Cieslinski 1980; Corti and others 1982; Lucas 1985b; Burde and Curran 1986); fewer visitors have been to the study wilderness before (Corti and others 1982; Lucas 1985b); and there are more women visitors (van Wagtendonk 1981; Lucas 1985b). There are few major conflicts in results from these few studies, although most of the characteristics reported on are not included in more than one or two of the studies, making comparisons difficult.

The number of projection studies is too small to draw conclusions about agreement or disagreement regarding level of projected use. A variety of approaches have been used, and it is not clear that a final answer on the best method has been found. The two earliest projections agreed very closely with one another, probably due to lucky accident. These projections were a little high to 1976, but not bad considering the difficulties involved. The later studies project widely varying annual average rates of growth, from less than 1 percent (Hof and Kaiser 1983a, 1983b) (in their low scenario using figures for primitive, dispersed camping, hiking/backpacking, and horseback riding), to over 7 percent (Jungst and Countryman 1982). These rates of growth have vastly different results over time; in 40 years a 1-percent-per-year rate results in a 49-percent increase, while a 7-percent rate leads to 1,400-percent growth! There is no consensus on the magnitude of projections of wilderness recreation. Projections are unlikely to improve until use estimates are improved, research increases our understanding of the factors related to changes in use, and better projections of these factors become available.

REFERENCES

Boteler, F. E. Eastern and western wildland users: a comparison of their characteristics with implications for management decision making. In: Proceedings of the conference on social research in National Parks and wildland areas; 1980 March 21-22; Gatlinburg, TN. Atlanta, GA: U.S. Department of the Interior, National Park Service, Southeast Regional Office; 1981: 99-106.

Bratton, Susan Power; Hickler, Matthew G.; Graver, James H. Trail and campsite erosion survey for Great Smoky Mountains National Park. Part II: Patterns of overnight backcountry use and conditions of campsites. Management Report 16. Gatlinburg, TN: U.S. Department of the Interior, Great Smoky Mountains National Park, Uplands Field Research Laboratory; 1977. 126 p.

Brown, Perry J. Information needs for river recreation planning and management. In: Proceedings, river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 193-201.

Brown, Perry J.; Haas, Glenn E. Relationships between resource attributes and psychological preferences of outdoor recreationists. Progress report submitted to U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO: Colorado State University, College of Forestry and Natural Resources; 1978. 19 p.

Brown, Perry J.; Haas, Glenn E.; Manfredo, Michael J. Identifying resource attributes providing opportunities for dispersed recreation. Final report submitted to U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station and Region 2. Fort Collins, CO: Colorado State University, College of Forestry and Natural Resources; 1977. 55 p.

Brown, Perry J.; Schomaker, John H. Criteria for potential wilderness campsites: final report submitted to the Intermountain Forest and Range Experiment Station. Supplement No. 32 to 12-11-204-3. Logan, UT: Utah State University, Institute for Study of Outdoor Recreation and Tourism; 1974. 50 p.

Bultena, Gordon L.; Taves, Marvin J. Changing wilderness images and forestry policy. Journal of Forestry. 59(3): 167-171; 1961.

Burch, William R. Wilderness—the life cycle and forest recreational choice. Journal of Forestry. 64(9): 606-610; 1966.

Burch, William R.; Wenger, Wiley D. The social characteristics of participants in three styles of family camping. Research Paper PNW-48. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1967. 30 p.

Burde, J. H.; Curran, K. A. User perception of backcountry management policies at Great Smoky Mountains National Park. In: Kulhavy, David L.; Conner, Richard N., eds. Wilderness and natural areas in the eastern United States: a management challenge; 1985 May 13-16; Nacogdoches, TX. Nacogdoches, TX: Stephen F. Austin University; 1986: 223-228.

Bureau of Outdoor Recreation. The 1970 survey of outdoor recreation activities: preliminary report. Washington, DC: U.S. Government Printing Office; 1972. 105 p.

Ciali, C. P.; Leonard, R. E.; Lindsay, J. J. Collecting hiker information in the backcountry: a methodological study. Recreation Management Program Research Report SNR-RM4. Burlington, VT: University of Vermont; 1978. 13 p.

Cieslinski, Thomas J. Trends in Allagash Wilderness Waterway uses. In: Proceedings, 1980 national outdoor recreation trends symposium; 1980 April 20-23; Durham, NH. General Technical Report NE-57, Vol. II. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1980: 147-149.

Clark, Roger N.; Johnson, Darryll R.; Field, Donald R. The Alaska public survey—a comprehensive assessment of recreational values and use patterns and natural resource management. In: Lime, David W., coord. Forest and river recreation: research update: selected papers presented at the symposium on leisure research, National Recreation and Park Association; 1981 October 25-27; Minneapolis, MN. Miscellaneous Publication 18. St. Paul, MN: University of Minnesota Agricultural Experiment Station; 1982: 115-119.

Cole, David N. Wilderness campsite impacts: effects of amount of use. Research Paper INT-284. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 34 p.

Cole, David N. Campsite conditions in the Bob Marshall Wilderness, Montana. Research Paper INT-312. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 19 p.

Corti, Adrienne; Petersen, Margaret E.; McCool, Stephen F. Trends in recreational use of the Rattlesnake National Recreation Area and Wilderness: a test of the designation hypothesis. A report submitted to the Wilderness Management Research Unit, Intermountain Forest and Range Experiment Station. Missoula, MT: University of Montana; 1982. 16 p.

Cushwa, Charles T.; McGinnes, Burd S.; Ripley, Thomas H. Forest recreation: estimates and predictions in the North River area, George Washington National Forest, Virginia. Bulletin 558. Blacksburg, VA: Virginia Polytechnic Institute, Agricultural Experiment Station, Department of Forestry and Wildlife Resources; 1965. 48 p.

DeLand, Loren F. Development of the Forest Service trail traffic counter. Test Report 7700-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center; 1976. 19 p.

Deutscher, J. What we say/what we do. Glenview, IL: Scott, Foresman and Co.; 1973. 370 p.

Dodds, Earl F. [Letters and attached visitor use surveys to Robert C. Lucas]. 1977 February 11. 23 leaves; 1978 February 22. 34 leaves. Located at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Missoula, MT; RWU 4901 files.

Driver, B. L.; Tocher, S. Ross. Toward a behavioral interpretation of recreational engagements, with implications for planning. In: Driver, B. L., ed. Elements of outdoor recreation planning: Proceedings of a national short course; 1968 May 6-16; Ann Arbor, MI. Ann Arbor, MI: University Microfilms; 1970: 9-31.

Echelberger, Herbert E.; Moeller, George H. Use and users of the Cranberry backcountry in West Virginia: insights for eastern backcountry management. Research Paper NE-363. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p.

Elsner, Gary H. Wilderness management. . . a computerized system for summarizing permit information. General Technical Report PSW-2. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1972. 8 p.

Field, Donald R. The telephone interview in leisure research. Journal of Leisure Research. 5(1): 51-59; 1973.

Gasvoda, David. Installation and operation of the Canon 814-XL camera traffic classification system. USDA Forest Service Manual. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Equipment Development Center; 1978. 9 p.

Gilbert, R. S. Dispersed winter recreation use in the Badger Pass backcountry of Yosemite National Park: challenges and opportunities. In: Proceedings, North American symposium on dispersed winter recreation; 1980 February 27-29; St. Paul, MN. Office of Special Programs-Educational Series 2-3. St. Paul, MN: University of Minnesota, Agricultural Extension Service; 1980: 114-117.

Haas, Glenn E. Points of origins of the Indian Peak backcountry recreationists. Addendum to final report: Identifying resource attributes providing opportunities for dispersed recreation. Submitted to U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station and Region 2. Fort Collins, CO: Colorado State University, College of Forestry and Natural Resources; 1978a. 5 p.

Haas, Glenn E. Quantification of preferences for dispersed outdoor recreation--Weminuche Wilderness phase. Progress Report. Weminuche Wilderness recreation use statistics. Fort Collins, CO: Colorado State University, Department of Recreation Resources; 1978b. 15 p.

Haas, Glenn E. Use preferences for recreation experience opportunities and physical resource attributes in three

Colorado wilderness areas. Fort Collins, CO: Colorado State University, Department of Recreation Resources; 1979. 141 p. Ph.D. dissertation.

Haas, Glenn E.; Arnold, J. R.; Brown, Perry J.; Driver, B. L. Final report of research results for the cooperative management-research demonstration project focusing on the Maroon Bells-Snowmass Wilderness in Colorado. Submitted to U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO: Colorado State University, College of Forestry and Natural Resources; 1982. 93 p.

Hammitt, W. E.; Hughes, J. L. Characteristics of winter backcountry use in Great Smoky Mountains National Park. Environmental Management. 8(2): 161-166; 1984.

Heberlein, Thomas A. Social psychological assumptions of user attitude surveys: the case of the wilderness scale. Journal of Leisure Research. 5(3): 18-33; 1973.

Heberlein, Thomas A.; Dunwiddie, Peter. Systematic observation of use levels, campsite selection and visitor characteristics at a high mountain lake. Journal of Leisure Research. 11(4): 307-316; 1979.

Helgath, Sheila F. Trail deterioration in the Selway-Bitterroot Wilderness. Research Note INT-193. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 15 p.

Hendee, John C.; Catton, William R., Jr.; Marlow, Larry D.; Brockman, C. Frank. Wilderness users in the Pacific Northwest: their characteristics, values and management preferences. Research Paper PNW-61. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968. 92 p.

Hendee, John C.; Clark, Roger N.; Dailey, Thomas E. Fishing and other recreation behavior at high mountain lakes in Washington State. Research Note PNW-304. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1977. 27 p.

Hendee, John C.; Stankey, George H.; Lucas, Robert C. Wilderness management. Miscellaneous Publication No. 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 381 p.

Hill, J. M. A comparative study of student awareness with United States Forest Service recommended methods of wilderness conduct. Salt Lake City, UT: University of Utah; 1975. (Pages unknown). M.S. thesis.

Hof, John G.; Kaiser, H. Fred. Long-term outdoor recreation participation projections for public land management agencies. Journal of Leisure Research. 15(1): 1-14; 1983a.

Hof, John G.; Kaiser, H. Fred. Projections of future forest recreation use. Resource Bulletin WO-2. Washington, DC: U.S. Department of Agriculture, Forest Service; 1983b. 12 p.

Hughes, J. L. Winter backcountry campers in the Great Smoky Mountains National Park: their behavior, use patterns, and characteristics. Knoxville, TN: University of Tennessee; 1985. 116 p. M.S. thesis.

Huppuch, Charles; Pellerin, Michael. Validation of trailside registration stations by volunteers. In: Proceedings, southeastern recreation research conference; 1984 February 16-17; Asheville, NC. Athens, GA: University of Georgia, Institute for Behavioral Research; 1984: 23-28.

James, George A.; Schreuder, Hans T. Estimating use in the San Gorgonio Wilderness. Journal of Forestry. 69(8): 490-493; 1971.

James, George A.; Schreuder, Hans T. Estimating dispersed recreation use along trails and in general undeveloped areas with electric-eye counters: preliminary findings. Research Note SE-181. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1972. 8 p.

Jubenville, Alan. A test of difference between wilderness recreation party leaders and party members. Journal of Leisure Research. 3(2): 116-119; 1971.

Jungst, Steven E.; Countryman, David W. Two regression models for projecting future wilderness use. Iowa State Journal of Research. 57(1): 33-41; 1982.

Keegan, Charles E.; Lenihan, Mary L.; Polzin, Paul E.; Wallwork, Susan Selig. The Montana poll: Montanans and wilderness issues. Montana Business Quarterly. 20(2): 4-14; 1982.

Kennedy, James J.; Brown, Perry J. Attitudes and behavior of fishermen in Utah's Uinta Primitive Area. Fisheries. 1(6): 15-17, 30-31; 1976.

Knopf, Richard C.; Lime, David W. A recreation manager's guide to understanding river use and users. General Technical Report WO-38. Washington, DC: U.S. Department of Agriculture, Forest Service; 1984. 37 p.

Kraushaar, James; Parsons, David; Stohlgren, Thomas. Nature and extent of differences between actual and planned backcountry use in Sequoia and Kings Canyon National Parks. In: Abstracts, 2d conference on scientific research in the National Parks; 1979 November 26-30; San Francisco, CA. Washington, DC: U.S. Department of the Interior, National Park Service; 1979: 176. Abstract.

Krumpe, E. E.; Brown, P. J. Redistributing backcountry use through information related to recreation experiences. Journal of Forestry. 80(6): 360-362, 364; 1982.

LaPage, Wilbur F. Some observations on campground trampling and ground cover response. Research Paper NE-68. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1967. 11 p.

LaPage, Wilbur F.; Ragain, Dale P. Trends in camping participation. Research Paper NE-183. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1971. 22 p.

Leatherberry, Earl C.; Lime, David W. Unstaffed trail registration compliance in a backcountry area. Research Paper NC-214. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981. 11 p.

Lee, Robert G. The management of human components in the Yosemite National Park ecosystem. Yosemite, CA: The Yosemite Institute; 1975. 134 p.

Leonard, R. E.; Echelberger, N. E.; Plumley, H. J.; van Meter, L. W. Management guidelines for monitoring use on backcountry trails. Research Paper NE-428. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1980. 20 p.

Leonard, R. E.; Echelberger, H. E.; Schnitzer, M. Use characteristics of the Great Gulf Wilderness. Research Paper NE-428. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1978. 9 p.

Lime, David W. Large groups in the Boundary Waters Canoe Area—their numbers, characteristics, and impact. Research Note NC-142. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1972. 4 p.

Lime, David W. Sources of congestion and visitor dissatisfaction in the Boundary Waters Canoe Area. In: Proceedings, the Quetico-Superior Foundation 1975 Institute on the BWCA; 1975 May 9; Duluth, MN. Minneapolis, MN: Quetico-Superior Foundation; 1975: 68-82.

Lime, David W.; Buchman, Roland G. Boundary Waters Canoe Area visitor use estimates: 1973 and 1974. Office Report. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1975. 77 p.

Lime, David W.; Knopf, Richard C.; Peterson, George L. The national river recreation study: growing new data base with exciting potential. In: Lime, David W.; Field, Donald R., tech. coords. Some recent products of river recreation research. General Technical Report NC-63. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981: 1-8.

Lime, David W.; Lorence, Grace A. Improving estimates of wilderness use from mandatory travel permits. Research Paper NC-101. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1974. 7 p.

Lime, David W.; Lucas, Robert C. Good information improves the wilderness experience. Naturalist. 28(4): 18-20; 1977.

Lucas, Robert C. Bias in estimating recreationists' length of stay from sample interviews. Journal of Forestry. 61(12): 912-914; 1963.

Lucas, Robert C. The recreational use of the Quetico-Superior area. Research Paper LS-8. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1964a. 50 p.

Lucas, Robert C. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Natural Resources Journal. 3(3): 394-411; 1964b.

Lucas, Robert C. The changing recreational use of the Boundary Waters Canoe Area. Research Note NC-42. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1967. 4 p.

Lucas, Robert C. Pilot test of traffic counter—movie camera equipment for measuring and classifying trail recreational use. Spanish Creek trail, Spanish Peaks Primitive Area, Montana. Data collected 1977 August. Located at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Missoula, MT; RWU-4901 files.

Lucas, Robert C. Low compliance rates at unmanned trail registers. Research Note INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 6 p.

Lucas, Robert C. Use patterns and visitor characteristics, attitudes, and preferences in nine wilderness and other roadless areas. Research Paper INT-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 89 p.

Lucas, Robert C. Redistributing wilderness use through information supplied to visitors. Research Paper INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 15 p.

Lucas, Robert C. Recreation regulations—when are they needed? Journal of Forestry. 80(3): 148-151; 1982.

Lucas, Robert C. Low and variable visitor compliance rates at voluntary trail registers. Research Note INT-326. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 5 p.

Lucas, Robert C. Recreational trend information and management of the Bob Marshall Wilderness complex. In: Proceedings, outdoor recreation trends symposium II; 1985 February 24-27; Myrtle Beach, SC. Clemson, SC: Clemson University; 1985a: 309-316.

Lucas, Robert C. Visitor characteristics, attitudes, and use patterns in the Bob Marshall Wilderness complex, 1970-82. Research Paper INT-345. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985b. 32 p.

Lucas, Robert C. Section 10. A wilderness planning-application example. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 523-555.

Lucas, Robert C.; Kovalicky, Thomas J. Self-issued wilderness permits as a use measurement system. Research Paper INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 18 p.

Lucas, Robert C.; Oltman, Jerry L. Survey sampling wilderness visitors. Journal of Leisure Research. 3(1): 28-43; 1971.

Lucas, Robert C.; Schreuder, Hans T.; James, George A. Wilderness use estimation: a pilot test of sampling procedures on the Mission Mountains Primitive Area. Research Paper INT-109. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971. 44 p.

Lucas, Robert C.; Schweitzer, Dennis. Outdoor recreation surveys: length-of-stay bias and its correction by computer. Research Note LS-68. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1965. 2 p.

Manfredo, Michael J. Rawah and Commanche Big South use estimates. Fort Collins, CO: Colorado State University, Department of Recreation Resources; 1978a. 23 p. Unpublished report.

Manfredo, Michael J. Recreation use estimates for the Fitzpatrick Wilderness, Popo Agie Primitive Area and surrounding backcountry, and the Bridger Wilderness. Unpublished report to U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO: Colorado State University, Department of Recreation Resources; 1978b. 25 p.

Manfredo, Michael J.; Haas, Glenn E. Eagles Nest Wilderness use estimates. Fort Collins, CO: Colorado State University, Department of Recreation Resources; 1978. 22 p. Unpublished report.

Marion, Jeffrey L.; Merriam, L. C. Recreational impacts on well-established campsites in the Boundary Waters Canoe Area Wilderness. Station Bulletin AD-SB-2502. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1985. 15 p.

Marnell, Leo F. Methods for counting river recreation users. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 77-82.

Marnell, Leo; Foster, David; Chilman, Kenneth. River recreation research conducted at Ozark National Scenic Riverways 1970-1977: a summary of research projects and findings. Van Buren, MO: U.S. Department of the Interior, National Park Service; 1978. 139 p.

McAvoy, Leo H.; Hamborg, Roland. Wilderness visitor knowledge of regulations: a comparison of visitor contact methods. Journal of Interpretation. 9(1): 1-10; 1984.

McCool, Stephen F. Does wilderness designation lead to increased recreational use? Journal of Forestry. 83(1): 39-41; 1985.

McCool, Stephen F.; Stankey, George H. Trends in visitor attitudes toward wilderness fire management policy. Research Paper INT-357. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 7 p.

Merriam, L. C., Jr. A land use study of the Bob Marshall Wilderness Area of Montana. Bulletin 26. Missoula, MT: University of Montana, School of Forestry, Forest and Conservation Experiment Station; 1963. 190 p.

Merriam, L. C., Jr.; Ammons, R. B. The wilderness user in three Montana areas. St. Paul, MN: University of Minnesota, School of Forestry; 1967. 54 p.

Merriam, L. C., Jr.; Luding, Kay; Ammons, R. B. Glacier Park chalet visits: an introduction to wilderness experience. Research Note 2. Missoula, MT: Montana State University [now University of Montana], School of Forestry, Montana Forest and Conservation Experiment Station; 1965. 3 p.

Mullins, William H. Sawtooth Wilderness visitor use study-1975. 1975. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Missoula, MT.

Murray, Judith Buckley. Appalachian Trail users in the southern National Forests: their characteristics, attitudes, and management preferences. Research Paper SE-116. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1974. 19 p.

Nielsen, Joyce McCarl; Shelby, Bo. River-running in the Grand Canyon: how much and what kind of use? In: Proceedings, river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 160-177.

Oliveira, Ronald A.; Arthur, Louise; Papasravrou, Anastassios C. A distributed lag approach to forecasting wilderness use. Journal of Leisure Research. 15(1): 52-64; 1983.

Outdoor Recreation Resources Review Commission [ORRRC]. Wilderness recreation—a report on resources, values and problems. Study Report No. 3. Washington, DC: U.S. Government Printing Office; 1962. 352 p.

Petersen, Margaret E. Trends in recreational use of National Forest wilderness. Research Note INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 3 p.

Petersen, Margaret E. Improving voluntary registration through location and design of trail registration stations. Research Paper INT-336. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 8 p.

Plumley, H. J.; Peet, H. T.; Leonard, R. E. Records of backcountry use can assist trail managers. Research Paper NE-414. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1978. 19 p.

Purdy, Ken G.; Shaw, William W. An analysis of recreational use patterns in desert bighorn habitat: the Pusch Ridge Wilderness case. In: Desert Bighorn Council transactions. Tucson, AZ: University of Arizona, School of Natural Resources; 1981: 1-5.

Reiling, S. D.; Montville, F. E.; Facchina, C. R. Baxter State Park: a profile of users, activities, and user attitudes, 1979. Bulletin 776. Orono, ME: University of Maine, Life Sciences and Agricultural Experiment Station; 1981. 40 p.

Robertson, Rachel Dawn. An investigation of visitor behavior in wilderness areas. Iowa City, IA: University of Iowa; 1981. 174 p. Ph.D. dissertation.

Roggenbuck, J. W. Wilderness user preferences: eastern and western areas. In: Proceedings of the wilderness management symposium; 1980 November 13-15; Knoxville, TN. Knoxville, TN: University of Tennessee; 1980: 103-146.

Roggenbuck, J. W.; Berrier, D. L. Communications to disperse wilderness campers. Journal of Forestry. 79(5): 245-297; 1981.

Roggenbuck, J. W.; Watson, A. E. Providing information for management purposes. In: Kulhavy, David L.; Conner, Richard N., eds. Wilderness and natural areas in the eastern United States: a management challenge; 1985 May 13-16; Nacogdoches, TX. Nacogdoches, TX: Stephen F. Austin University; 1986: 236-242.

Roggenbuck, Joseph W.; Berrier, Deborah L. A comparison of the effectiveness of two communication strategies in dispersing wilderness campers. Journal of Leisure Research. 14(1): 77-89; 1982.

Roggenbuck, Joseph W.; Timm, Wendy N.; Watson, Alan E. Visitor perception of the recreation carrying capacity of three wilderness areas in North Carolina. Blacksburg, VA: Virginia Polytechnic Institute and State University, School of Forestry and Wildlife Resources; 1979. 303 p.

Saunders, Paul Richard. Monitoring and reporting recreation use: a case study. In: Southeastern recreation research conference, 1980-1981: Proceedings; 1980 February 18-19; 1981 February 19-20; Asheville, NC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1982: 143-164.

Schomaker, J. H. Effect of selected information on dispersal of wilderness recreationists. Fort Collins, CO: Colorado State University; 1975. 95 p. Ph.D. dissertation.

Scotter, George W. Response rates at unmanned trail registers. Journal of Leisure Research. 13(2): 105-111; 1981.

Shafer, Elwood L., Jr.; Lucas, Robert C. Research needs and priorities for dispersed recreation management. Journal of Leisure Research. 10(4): 311-320; 1979.

Shaw, W. W.; Richards, M. T. Recreational and scientific activity in Cave Creek Canyon, Chiricahua Mountains, Arizona, 1978-79. Final report prepared for the Coronado National Forest, Forest Service, U.S. Department of Agriculture. Tucson, AZ: University of Arizona, School of Renewable Natural Resources; 1979. 22 p.

Shechter, M. On the use of home site surveys in recreation research. In: Elsner, Gary H., compiler. State-of-the-art methods for research, planning, and determining the benefits of outdoor recreation. General Technical Report PSW-20. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1977: 23-27.

Shechter, Mordechai; Lucas, Robert C. Simulation of recreational use for park management. Baltimore: Johns Hopkins University Press; 1978. 220 p.

Snowden, Michael R. Winter recreation in the Adirondack High Peaks Wilderness: user characteristics, attitudes and perceptions. Ithaca, NY: Cornell University; 1976. M.S. thesis.

Stankey, George H. Visitor perception of wilderness recreation carrying capacity. Research Paper INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 61 p.

Stankey, George H. Wilderness fire policy: an investigation of visitor knowledge and beliefs. Research Paper INT-180. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 17 p.

Stankey, George H. Use rationing in two southern California wildernesses. Journal of Forestry. 77(6): 347-349; 1979.

Stankey, George H.; Cole, David N.; Lucas, Robert C.; Petersen, Margaret E.; Frissell, Sidney S. The limits of acceptable change (LAC) system for wilderness planning. General Technical Report INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 37 p.

Stankey, George H.; Lucas, Robert C.; Lime, David W. Crowding in parks and wilderness. Design and Environment. 7(3): 38-41; 1976.

Stone, Gregory P.; Taves, Marvin J. Research into the human element in wilderness use. In: Proceedings, Society of American Foresters, 1956; 1956 October 15-17; Memphis, TN. Washington, DC: Society of American Foresters; 1957: 26-32.

Superior National Forest. Wilderness use estimates—1984. 1984. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Superior National Forest, Duluth, MN.

Taves, Marvin J.; Hathaway, William; Bultena, Gordon. Canoe country vacationers. Miscellaneous Report 39. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1960. 28 p.

Taylor, Dorothy T.; Mackoy, Robert D. Winter recreation in the White Mountains: users' characteristics and information needs. Gorham, NH: Appalachian Mountain Club, Research Department; 1980. 103 p.

Taylor, Dorothy T.; Spencer, Edward L. Participant profile of backcountry winter recreationists. In: Proceedings, North American symposium on dispersed winter recreation; 1980 February 27-29; St. Paul, MN. Office of Special Programs-Educational Series 2-3. St. Paul, MN: University of Minnesota, Agricultural Extension Service; 1980: 20-24.

Thorsell, J. W. A trail use survey: Banff and Yoho National Park, 1967. Recreational Research Report 33. [Place of publication unknown]: National Parks Service-Planning, National and Historic Affairs Branch, Department of Indian Affairs and Northern Development [Canada]; 1968. 57 p.

Timm, W. N. A comparison of the carrying capacity perceptions of eastern and western wilderness users. Blacksburg, VA: Virginia Polytechnic Institute and State University; 1980. 125 p. M.S. thesis.

U.S. Department of Agriculture, Forest Service. NFRS [National Forest Recreation Survey] Form No. 10. Table G, summary of NFRS. Forest Service Summary, Appendix 18. Washington, DC; 1961. 2 p.

van Wagtendonk, Jan W. The effect of use limits on backcountry visitation trends in Yosemite National Park. Leisure Sciences. 4(3): 311-323; 1981.

van Wagtendonk, Jan W.; Benedict, James M. Wilderness permit compliance and validity. Journal of Forestry. 78(7): 399-401; 1980.

Washburne, Randel F.; Cole, David N. Problems and practices: a survey of managers. Research Paper INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 56 p.

Wenger, Wiley D., Jr. A test of unmanned registration stations on wilderness trails: factors influencing effectiveness. Research Paper PNW-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1964. 48 p.

Wenger, Wiley D., Jr.; Gregersen, H. M. The effect of non-response on representativeness of wilderness trail register information. Research Paper PNW-17. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1964. 20 p.

Wuerthner, George. Managing the wild back into wilderness. Western Wildlands. 11(3): 20-24; 1985.
Young, Robert A. An analysis of wilderness concepts and values. Urbana, IL: University of Illinois; 1978. [Pages unknown.] Ph.D. dissertation.
Young, Robert A. Toward an understanding of wilderness participation. Leisure Sciences. 5(4): 339-358; 1983.

AUTHORS

Joseph W. Roggenbuck
Associate Professor, School of Forestry and Wildlife
Virginia Polytechnic Institute and State University
Blacksburg, VA 24060

Robert C. Lucas
Project Leader
Intermountain Research Station
Forest Service, U.S. Department of Agriculture
Missoula, MT 59807

ATTITUDES TOWARD WILDERNESS AND FACTORS AFFECTING VISITOR BEHAVIOR: A STATE-OF-KNOWLEDGE REVIEW

George H. Stankey and Richard Schreyer

ABSTRACT

An understanding of user attitudes is essential to effective wilderness management. This review outlines historical and current societal and individual attitudes toward wilderness, reasons for participating in wilderness, factors affecting wilderness behavior (including attitudes toward management, crowding, and conflict), and how information and education affect behavior.

Visitors usually have distinct attitudes, though they vary considerably, and desire a role in the management process. Their views are increasingly important in the decision-making process. Research has a vital role in validating visitor input and presenting results to management in a timely and useful manner.

INTRODUCTION

How do people perceive wilderness? What factors influence their decisions to visit wilderness and what they do once there? What is the role of visitor attitudes and perceptions about wilderness in the management of these areas? Such questions underlie efforts to understand the meaning and significance of wilderness in society today.

In this paper, we review the state of knowledge regarding attitudes toward, and behavior within, wilderness. We are concerned with how people (typically, but not necessarily, visitors) feel about wilderness—the setting, use, and management. The actual behavior of wilderness recreationists—the types and lengths of trips, spatial and temporal patterns of use, and the activities in which people participate—is described in the review paper by Roggenbuck and Lucas (this proceedings). Our focus is on the factors that **influence** behavior—perception, education and information, group pressures, and so forth.

Because attitudes act as one influence on behavior, an understanding of their direction, intensity, strength, and distribution across the relevant population are all essential to effective wilderness management. Feedback from well-designed social surveys can provide a better understanding of the beliefs, ideas, and concerns held by visitors and other citizens. Such data also can help dispel the biases and misconceptions that arise from selective perception and contact (Lucas 1980).

We have focused our literature review on material dealing with the attitudes and behavior of individuals using environments characterized by relatively low use densities, few facilities, and where other resource development activities were prohibited or greatly restricted.

Many of the findings about the recreation behavior process that we report here have their roots in work done in nonwilderness settings. Wilderness and its visitors exist within a complex, interacting system of recreation environments; the institutional labels applied to such areas often have little bearing on how they are perceived and used. Movement within this system is fluid over both space and time. Indeed, it is the images and conceptions of wilderness and their influence upon visitors' use that serve as the focus of this review.

The presentation will initially examine the formation and evolution of societal attitudes toward wilderness. These broad, cultural conceptions have obvious influences on individual perceptions; they serve also to highlight the continually shifting nature of the perceived relationships between society and nature. We then shift to a more specific level of analysis, examining the motives underlying wilderness participation and the general question of why people seek out these settings (this issue is explored in more detail in the paper on wilderness benefits in these proceedings by Driver and others). We then explore environmental perception, focusing on how the images people have about wilderness are formed and modified and how they affect behavior. Next, we review the breadth and distribution of opinions held by wilderness recreationists toward management actions and policies that have been, or might be, implemented. Finally, our review examines conflict in the wilderness setting and the general literature on crowding and carrying capacity.

We close with a brief analysis of the extent to which research findings regarding attitude and behavior have been applied. We also suggest areas of needed research.

EVOLUTION OF SOCIETAL ATTITUDES TOWARD WILDERNESS

We begin our review of America's disposition toward wilderness at the society level. A society's conception of its environment and the relationship between itself and that environment are a product of a variety of experiences and influences. The attitudes about, and the behavior toward, wilderness in the United States reflect this: to fully understand modern society's view of wilderness, one needs to understand something of the socio-cultural history out of which the country and its people evolved.

Early Conceptions of Wilderness

Nash's "Wilderness and the American Mind" (1982) provided us with an excellent summary of Old World images of wilderness that served as a frame of reference for early American colonists. Although wilderness, in American terms, exists in only a few isolated places in modern Europe, during the Middle Ages it was a significant and familiar component of the landscape. But it was less the physical familiarity with wild lands and more the place of wilderness in mythology and religion that shaped the common view of wilderness.

In the simplest sense, wilderness was the antonym of paradise. Whereas paradise was ordered, beneficent, and supportive of the human way, wilderness was foreboding, evil, and threatening. This image was communicated and reinforced through various media; both classical mythology and the folklore of various European tribes conveyed the idea of wilderness as a place beyond human control, a place of demons, monsters, and devils, of strange, grotesque beasts. Indeed, it is in the epic Anglo-Saxon story of Beowulf that we encounter use of the word "wildeor," a wild animal, which Nash identified as the etymological root of "wild-deor-ness," the place of wild beasts, and eventually the word wilderness.

Certainly the Biblical use of wilderness further reinforced such negative connotations. From the downfall of Adam and Eve and their banishment from the garden (paradise) to the 40-year wanderings of Moses and the Israelites in the Sinai Peninsula, wilderness described the setting to which individuals were exiled.

Yet, these early episodes also contain the first hint of a countervailing attitude toward wilderness. Added to the traditionally accepted dreadful image of wilderness was the idea that wilderness was a place where one could seek sanctuary from a fallen society, where one could find God, and where people could be purged and cleansed prior to finding the Promised Land. All these images conceived of wilderness not as a place of worth or merit itself, but rather as a means of achieving paradise. They represented the recognition of utility and value of wilderness, contrasted to the negative images typically associated with it.

As the European population grew and agriculture and industrialization spread, the wilderness landscape rapidly diminished. Although the rate of change varied throughout the area, it is generally agreed that the changes occurred sufficiently fast so that the forests of the region often did not reach equilibrium with the climate before they were destroyed or modified by human action (Poore and Gryn-Ambroes 1980). Conceptions and images of wilderness carried by early American colonists were strongly influenced by the religious dogma that dominated their culture. In many ways, the worst fears of these early settlers were realized when they first came in contact with the North American wilderness. The sheer immensity of it was beyond anything they could believe. The few remnants of wild land remaining in Europe were restricted to small, discrete pieces of country—a peak or a valley. In America, it stretched on endlessly. It was not only a physical barrier to movement, but it also harbored wild animals, Indians, and other threats. In a variety of ways, the American wilderness fit to perfection the belief, fabricated over generations in Europe, of a place that harbored anti-Christian forces. Perhaps even more serious than its role as a barrier to progress or as a sanctuary for forces threatening to settlers was its capacity to lead man to succumb to the wildness of his surroundings (Graber 1976). Unless constant vigil was maintained, the thin veneer of civilization could be lost, reducing man to a condition, as one early writer noted, "no better than carnivorous animals of a superior rank" (Nash 1982).

The early conception of wilderness in North America was dominated by fear and abhorrence. Period literature is full of references to wilderness as desolate, a howling wasteland, a godless tract. Although these accounts are derived from a relatively small segment of the society, they are typically the opinions of key community leaders, particularly spokesmen of the religious institutions. There seems little reason to believe that the North American wilderness held much for early settlers other than fear and foreboding.

But attitudes are not static. Attitudes are the product of a variety of influences and conditions and, as these change, attitudes change as well. As eastern seaboard settlement took root and westward expansion occurred, the image of wilderness evolved further.

Shifting Attitudes Toward Wilderness

These tentative changes in attitude were not the forerunners of a major revolution in thinking about wilderness (Dearden and Sewell 1985). They do constitute a point at which ambivalence again began to emerge; wilderness was seen not only in its traditional role as a barrier to progress and a potential contaminant of the human spirit but also as a source of some more positive human value. What began to emerge as America grew was a view, albeit a minority perspective, that the wilderness landscape held value in and of itself, that it was not just the material from which civilization was to be fabricated. Nash (1982) noted that the concept of sublimity gained widespread usage in the 18th century. In the spirit of that age, the wilderness setting was considered pleasing, and emotional reactions to it were ones of awe and exultation rather than dread and loathing.

This tentative shift represents a critical point in our history; the symbolic representation of wilderness began to change. As Tuan (1974) has noted, the human capacity for symbolic behavior is great. For generations, wilderness was a symbolic manifestation of a great many things contrary to human welfare. As the 19th century began to unfold, we see, if not a rejection of this symbolism, at least a differentiation in it. This change raises questions as to what factors might have been responsible for such a reorientation. A review of this era's history suggests several possibilities.

First, this period marked a time of rapid growth in scientific understanding. Actually, beginning in the 11th century, the scientific sector of European culture had increased greatly (White 1967). With it came an increasing understanding of the world and evidence that natural phenomena such as mountains and storms were not the result of a vengeful God's wrath, but rather the end product of predictable physical laws and processes. Growth of scientific understanding helped generate an appreciation of how nature in general, and wilderness in particular, revealed the glories of God; it contributed to a major shift from the traditional view in which such areas were seen as indicative of an absence of holy influence (Huth 1957).

Second, several authors have argued that the emergence of an appreciation for the vast wilderness of North America was the result of the search for a distinctive American culture (Lowenthal 1968; Nash 1982). Because the country's youthfulness largely precluded significant achievements in art or literature, America's cultural development was meager compared to that of Europe, and the lack of such accomplishments could not be fully offset by the new nation's flourishing economy or stable government. But ironically, the art and literature of the romanticists, much of it created by Europeans, helped generate an appreciative attitude regarding nature. Increasingly, Americans came to realize that a distinctive aspect of their culture was one not only absent from Europe, but one not even capable of being created there: vast, unfettered nature, represented in the wilderness of North America. Gradually a notion that appreciated certain values of wilderness began to take form.

A third factor was the gradual emergence of an urban population. At the onset of American settlement, pioneers confronted wilderness in a direct manner; there was no buffer to soften the impact, and survival was paramount. The lack of any deep affection for the raw natural surroundings against which they found themselves pitted was hardly surprising. But as distance between mainstream society and the wilderness frontier began to increase, so did the capacity for an appreciative stance, spurred by factors such as the rise of romanticism.

The beginning of westward expansion also marked the beginning of the diminution of what once was considered an endless tract of wilderness. The finiteness of wilderness and the fact that it could become scarce found its way into the American psyche, an important precondition to the recognition of wilderness as a public good (McCloskey 1966).

Although these changes in attitude did not constitute broad, pervasive shifts in public opinion, they were significant. They set the stage for a period during which recognition of wilderness values began to be supplemented by actions in the public policy arena.

The 1800's marked a significant turning point in America's relationship to wilderness. This shift turned on two fronts. First, there was continuing growth in the intellectual conceptualization of wilderness and its relationship to human society. Romanticism played a key role in this development; it viewed wilderness as sublime and a physical reality vital to society. As Nash (1982) noted, however, romanticism never seriously challenged the dominant pioneer attitudes toward wilderness; it merely provided momentary respite from the general antipathy toward such areas. Romanticism did not reject man's long-term dominating stance toward wild nature; it required only recognition of a broadened symbolic wilderness in which the beauty of such areas and their strengthening qualities to the human spirit were admitted.

Belief in a more fundamental function for wilderness relative to society contributed to a rise in the transcendentalist view. Transcendentalism implied that a higher realm of spiritual truth paralleled the plane at which material reality existed and that it was possible, through intuition or imagination, for an individual to achieve this higher plane of consciousness. The more unfettered and uncontaminated the natural setting, the better it could facilitate spiritual insight and moral improvement.

Transcendentalism is well represented in the writings of Thoreau. Thoreau encapsulated this philosophical stance when he pronounced, in 1851, that "in Wildness is the preservation of the world." Wildness and its physical manifestation as wilderness, in the view of the transcendentalists, were essential to society's understanding of its relationship to God. In a reversal of earlier Puritan views, the inherent goodness of mankind could only be realized through the presence of wild nature.

Thus, the first major development in the 19th century that set the stage for a societal shift in attitude toward wilderness was the formulation of a philosophical framework within which such areas could be defined as contributing to human welfare. Although such a framework did not enjoy universal acceptance, it provided an alternative perspective that would serve as the basis for later, more profound alterations in America's view of preservation.

The second major activity in the 1800's involved the first calls for action to preserve wilderness. Twenty years prior to Thoreau's famous pronouncement, George Catlin, a lawyer, painter, and student of the American Indian, had introduced the concept of "a nation's Park, containing man and beast, in all the wildness and freshness of their nature's beauty" (cited in Nash 1982). Catlin's remarks were motivated both by his observation of the rapid disappearance of the wilderness as well as his concern with the contaminating influences of civilization on the wilderness.

Such pronouncements raised the issue of protection of wilderness values to a public, and therefore, political level. Calls for protection began to find realization in the second half of the 19th century. In 1864, the Federal government granted the State of California lands in Yosemite Valley for the purpose of preservation. In 1872, Yellowstone National Park was established as the world's first such reserve. It was followed in 1885 with creation of the Adirondack Forest Preserve by the State of New York, and in 1890, by Yosemite National Park, according to Nash (1982) the first park consciously designed to preserve wilderness.

Wilderness preservation was not the primary motivating factor for early protection. In the case of Yellowstone, designation was to prevent the area's "curiosities" from being taken up in private ownership while in the Adirondacks protection of valuable watersheds was the principal concern. Even in the case of Yosemite, the enabling legislation did not contain specific language citing wilderness preservation as an objective.

Much of this early action focused on the protection of areas with special qualities, such as the thermal features of Yellowstone, rather than on the protection of large tracts of undeveloped land that lacked any distinguishing values other than their naturalness. Even when protection was provided, support in the form of Congressional appropriations was often lacking. Without the intervention of the U.S. Cavalry, several National Parks, including

Yellowstone, Yosemite, and Sequoia, would have been exploited in the latter part of the 19th century (Hampton 1971).

Nonetheless, these actions provide evidence of a major revamping of social values, a shift of amazing proportions, because only a few decades earlier such actions likely would not have been even considered, let alone undertaken.

The ambivalence permeating evolving philosophical and religious thought over the years also was reflected in the policies of government. At the same time that precedent-setting actions of preservation were taking place, traditional views of progress and development were further codified through a variety of government policies and laws. These included the Pre-emption Act of 1841, the various Homestead Acts beginning in 1862, the General Mining Law of 1872, the Timber Culture Act of 1873, and the Desert Land Act of 1878. Such actions helped sustain not only the physical occupancy of the wilderness, but also reinforced the attitude that the Nation's duty was to subdue and develop remaining wild lands.

From roughly the last decade of the 19th century through the first two decades of the 20th century, a great transition occurred in America's attitude toward wilderness. Over this time, the negative evaluation of wilderness and support for its elimination were replaced by significant concern that at least some wilderness should be preserved.

This period of transition featured a gradual rethinking of the relationship between wilderness and society, characterized then, as well as now, by conflicting interests and competing values of the worth of wilderness. What was significant in this shift was the emerging view that the struggle between wilderness and civilization was not a matter of a conflict between good and evil but rather a debate over two goods, with resolution based on a judgment of the relative priorities associated with each.

The place of wilderness on the national agenda, in a historical sense, altered with amazing speed. What were the driving forces that underlay this shift? Why, in the 1850's, did Thoreau find little receptiveness for his views about the role of wilderness in civilization, yet in 1913, John Muir and Robert Underwood Johnson were able to elevate the Hetch Hetchy controversy into a major national issue, commanding the personal attention of the President?

Wilderness in 20th-Century America

At least three merging phenomena of late 19th-century and early 20th-century America help explain much of our new view of wilderness. First, the seemingly unending wilderness against which significant struggle was required in order to establish European-style civilization was simply disappearing. With the 1890 Census, the frontier was officially declared gone and, with it, the environmental conditions that had spawned much of the unique American character. Moreover, there was no need to maintain the antagonistic relationship with wilderness; westernization had won. Second, the intellectual and emotional base for the support of wilderness from scientific, philosophical, and religious perspectives had undergone great change during the latter 1800's. Increasingly, good reasons from a variety of perspectives could be offered in support of wilderness. Third, America was undergoing the growing pains of an emerging industrial civilization and many of the aspects of this new society were distressing. The slums, the squalor, the dehumanizing treatment of industrial workers all contributed to a rising concern that too much civilization, like too much wilderness, was not a good thing, and that as the distance from our wilderness origins increased, so did the need for continued contact with such settings.

With the momentous changes in the American landscape and society in the late 1800's, the period around the turn of the century was pivotal for wilderness support. Activity supporting the goals of preservation could be found in both the public and private sector. In 1892, for example, Muir, along with several professors from the University of California and Stanford, established the Sierra Club. It followed the precedent, established nearly 20 years earlier by the Appalachian Mountain Club, of uniting people with an interest in the out-of-doors. Although only one of several such organizations founded during this period, it clearly laid out its concern by mobilizing public support for governmental action to preserve the environment.

In 1916, the creation of the National Park Service represented a significant, long-term commitment by government to ensure protection of segments of primitive America and was an important consequence of the earlier steps taken to preserve Yellowstone and Yosemite. This action was in part due to growing public concerns with protection of natural values. In large part, however, it was a result of vigorous efforts by Stephen Mather to secure support for creation of the agency among key opinion leaders across the Nation. Between Mather and Robert Sterling Yard, over 1,000 magazine articles were published in support of the National Parks in 2 years and 275,000 copies of an illustrated book about the parks were distributed free to the Nation's opinion leaders (Fazio and Gilbert 1981).

Such a broad-scale shift in public and governmental attitudes was essential to any substantial growth in the wilderness idea. As Nash (1982) noted, possibly the significance of the Hetch Hetchy controversy is less the particular outcome of the debate than the fact that it occurred at all. Although conflicts remained and would continue, early 20th-century America had reached a point where the preservation of wilderness was increasingly viewed as important. From the 1920's until the present, the long-developing positive conception of wilderness in America gained broad public support.

The 60-year period between 1924 and the present can be broken into two subunits in terms of attitudes toward wilderness preservation. Between 1924 and 1964, there was an increasing maturation in the wilderness concept, expansion in public support, and growth in the role of government in wilderness preservation, and in its institutionalization as a land use. The period was initiated by the landmark reservation in 1924 of the 574,000-acre Gila Wilderness in New Mexico, largely through the efforts of Aldo Leopold. This action represented the first formal dedication of an area to wilderness purposes, setting the stage for creation of a system of land use reservations that would match the National Park System in terms of its international precedence and significance.

The Gila Wilderness designation was followed shortly by a major inventory of remaining wilderness lands in the continental United States. The results confirmed that wilderness was diminishing. Such information provided support for creation of the first formal and systematic organizational program to achieve wilderness preservation goals—the L-20 program instituted by the Forest Service in 1929. Deeply imbedded reservations about wilderness remained, and it is interesting to note that the L-20 program created a system of "primitive areas" rather than wilderness areas, a step purposely taken because of concerns about public opposition to the establishment of wilderness. Ten years later, efforts by Bob Marshall, the dynamic and imaginative proponent of wilderness and then Director of Recreation for the Forest Service, led to a revised set of administrative procedures for the establishment and protection of a system of wilderness and wild areas on the National Forests. This new system was intended to gradually replace the earlier L-20 program and provide a more rigorous approach to wilderness preservation. Formerly permitted developmental activities were more tightly regulated and wilderness preservation purposes more clearly defined (Hendee and others 1978).

In approximately one decade, from institution of the L-20 regulation until the outbreak of World War II, over 14 million acres were set aside as wilderness on the National Forests. Additionally, the first explicit recognition of wilderness values was written into the enabling legislation for Everglades National Park. Clearly, the concept of wilderness had obtained a credibility sufficient to establish it as a legitimate value and land use. Rather than being an assumed or implicit quality, it now received recognition in and of itself.

However, the recurring theme of conflicting societal goals soon reasserted itself. Following the end of World War II, increasing demands, especially on the National Forests, for timber products soon brought the goals of a developing and expanding society into conflict with those of preservation. A similar kind of conflict, albeit different in form, occurred in the National Parks, as use levels and demands for services grew rapidly. Many felt that wilderness was considered only as a residual value and that when conflicts with traditional values and uses arose, wilderness would always lose. Moreover, the establishment of new wildernesses appeared viable only if it could be demonstrated that such areas did not involve the loss of any significant monetary values. Wilderness protection was a defensive activity, dependent on the good will and discretion of sympathetic administrators.

Concerns with the long-term protection of wilderness reached a peak in the mid-1950's with introduction of the initial bill to establish a National Wilderness Preservation System. In the ensuing 8 years, any doubts that wilderness had achieved broad recognition and support as a political issue were dispelled. Its tenacity was impressive; it reappeared with each Congressional session over 8 years, each time with more force. The wilderness issue and its supporters became intensely politicized. Literally thousands of pages of testimony were received, hearings were held nationwide, and Congress was flooded with letters, resolutions, and petitions. Few, if any, items had ever received the level of public attention over such an extended period. Moreover, it was a time when wilderness advocacy groups acquired new levels of skill and expertise in dealing in the political arena, skills they would later use to even greater advantage. When the final wilderness bill was voted on, both Houses of Congress passed it with overwhelming majorities (see Allin 1982 for details of the Congressional debate over the Wilderness Act).

Passage of the Wilderness Act in 1964 constituted support for wilderness at the highest level of government and represented a transition to the second period in the recent history of wilderness. If one assumes that the actions of Congress reflect an estimation on that body's part of the interests and needs of American society, it is clear that an extraordinary shift in American attitude toward wilderness had occurred over a period of scarcely more than a century. The act represents an expression of nationwide support for the concept of wilderness as well as an expression of society's intent to back that attitude with action. As we shift attention to the second component of our recent historical review, the period from 1964 until the present, we will examine some indicators of this intention that reflect American attitudes and behavior with regard to wilderness.

At the time the Wilderness Act passed, more than 9 million acres were included in the National Wilderness Preservation System (NWPS). It was not clear how much wilderness might eventually be set aside, although Howard Zahniser, the Wilderness Society's principal architect of the act, estimated that perhaps 50 million acres might be included (Nash 1982). However, at the end of 1984, two decades after passage of the act, the NWPS had swollen to nearly 89 million acres, with the designation of many millions more pending. Over 60 separate pieces of legislation had worked through the elaborate and, at times, tortuous Congressional approval system to reach final passage. The NWPS has continued to grow, even though a wide spectrum of political ideologies have been represented in Congress as well as the White House. This virtual tenfold expansion in classified wilderness in 20 years is an impressive manifestation of the priority of wilderness on the national political agenda and its remarkable capacity to sustain itself in the minds of politicians and the public.

The political significance of wilderness has ensured that it remain a major concern for administrative agencies. For example, in less than one decade the Forest Service has undertaken two major reviews of the extent of roadless, undeveloped lands in the National Forest System, with the objective of recommending to Congress new additions to the NWPS. Both reviews (Roadless Area Review and Evaluation, RARE I and II) have been expensive, time-consuming efforts; public demands for information as well as high-quality performance in the conduct of these reviews have been considerable. During RARE I, for example, 300 public meetings were held nationwide, with over 25,000 persons in attendance. Public input included 54,000 individual and/or group opinions, and 18,000 signatures on petitions. During RARE II, 5 years later, over one-quarter million inputs were received, containing over 360,000 signatures.

Similar intense public interest has been witnessed for wilderness issues in the National Parks. The General Management Plan for Yosemite National Park, for example, where substantial wilderness values are found, generated tremendous public involvement. The National Park Service conducted 48 workshops nationally, drawing 5,600 participants. An elaborate workbook was devised in which various management alternatives were outlined, along with a section where citizens could devise their own management alternative. Over 700 possible choices were involved and the average time to complete the workbook was estimated between 4 and 8 hours; nonetheless, 21,000 of the 60,000 distributed were completed and returned (Buck n.d.).

Summary

If we summarize the evolution of American attitudes toward wilderness over the past 250 years, several themes emerge. First, there has been a remarkable shift in those attitudes since the eastern seaboard was first settled by Europeans. Although the trend has not been even, the general tendency has been for a continually evolving conception that recognizes the importance of wilderness. The evolution has been driven by a variety of forces, including shifts of thinking among both scientists and philosophers, the increasing scarcity of wild land, and recognition of the value of retaining a diversity of environmental settings as a complement to an increasingly developed landscape.

Second, nature in general and wilderness in particular have commanded a central position on the political agenda. Wilderness has clearly achieved the status of a major public policy issue in America. While other issues will command attention from time to time, the importance of wilderness, especially its future stewardship, will remain a major concern.

Finally, the attitudes that society holds about wilderness, as well as those espoused by visitors to such areas, are critical to the planning and management of such areas. Therefore, science has a major responsibility to provide politicians, managers, and the citizenry with a comprehensive, accurate information base regarding these attitudes—their range, strength, and distribution—in order to facilitate the long-term preservation of wilderness.

Such attitudes include overall societal support for the concept of wilderness, factors influencing where to go as well as what to do while in wilderness, attitudes toward management, and the perception of other wilderness users. The next section examines factors affecting decisions about participation in wilderness recreation.

REASONS FOR PARTICIPATION IN WILDERNESS RECREATION

The overall purpose of this review is to explore the factors that influence people's attitudes about wilderness and their subsequent behavior in such areas. We want to understand better the "why's" behind these attitudes and behaviors. In the previous section we examined general societal views of the **concept** of wilderness. Now we want to take a closer look at specific attitudes and behaviors as they relate to actual wilderness use. In this section, we examine the factors that lead people to visit wilderness and affect their decision to participate.

The reason for wanting to participate is generally considered the motive for behavior. This motive must be translated to behavior through some choice process, which can be influenced by many situational factors. The object of choice might be a particular recreation environment, a behavior, or some desired psychological condition. The selection of a particular wilderness environment depends on the attributes in the environment perceived as being suitable for fulfilling the needs that initially motivated behavior. These three components—the motives that initiate behavior, the choice process to determine the type of behavior, and the attributes of environment that affect the place selected for behavior—will be discussed below.

Motives for Participation

The Semantics of Motivation.—Research on the topic of motivation in recreation has been filled with ambiguity. Different terms have been used to describe the forces initiating human behavior. We often say that people behave primarily to fulfill needs, and that a need represents a condition of human consciousness in which the individual perceives a relative deprivation in some aspect of existence. The concept of need is very plastic, ranging from universally shared needs, such as for food, to extremely individualized and contrived needs, such as for a video cassette recorder. Thus, the concept of need is a very broad way of representing forces that direct persons toward action with greater or lesser intensity.

A motive is considered to be a more or less consistent predisposition to act on a certain type or set of needs. The extent to which a given motive will direct behavior depends on the amount of perceived deprivation. Individuals can have a motive to experience nature that will direct them toward the selection of recreation activities in natural environments. This can result in an ongoing pattern of participation, but may have greater or lesser influence on any given decision.

Motives, like needs, are contrived notions. We can generate lists of motives for participation, and they might be more or less consistent over time. There is likely no universal list of motives, however, and the reasons for participation evolve as cultural and individual values evolve. Motives are a useful form of shorthand for representing the reasons why people engage in a certain type of behavior.

Reasons for engaging in recreation behavior have been conceived as "recreation experience preferences" (Driver 1976), in recognition of the fact that the forces that initiate behavior are voluntary and represent preferred conditions. If a certain need initiates behavior, we want that behavior to provide us with a payoff in terms of fulfilling that need. We walk into the wilderness because we have the desire to experience nature; thus, it is important that we do in fact experience nature. This payoff is seen as an outcome, and is why motives have also been referred to as "desired psychological outcomes" (Driver and Brown 1978) or "desired consequences" (Driver and Knopf 1977).

A particular behavior and environment are chosen in response to a given motivation primarily because the information available at that time leads us to expect that such behavior and environment will, in fact, produce the desired outcome. Thus, we participate in recreation with some expectation that we will encounter desirable conditions. This is why motives have also been represented as "experience expectations" (Schreyer and Roggenbuck 1978).

Needs, motives, experience expectations, recreation experience preferences, and desired psychological outcomes all represent slightly different ways of looking at the purpose that engaging in a given type of recreation is supposed to serve (Crandall 1980). Measurement of the extent to which these outcomes are attained is usually represented as satisfaction. If the expected outcomes are not forthcoming, the person is assumed to be dissatisfied with the recreation experience.

The outcomes provided through participation in a given environment provide insights into the psychological function of that particular type of recreation for the individual and, consequently, help establish the value of a particular use of a given environment. The paper "Benefits of Wilderness Participation" (Driver and others this proceedings) focuses on these payoffs. In this paper we focus primarily on reasons for the initiation of participation, though the forces cannot be separated completely.

Theoretical Approaches.—Recreation research on motivation has drawn on existing models from the psychological literature. The most frequently used model has been expectancy theory (Lawler 1973), in which the force behind a given behavior is a function of the strength of expectancy that an outcome will result from a particular behavior in a given environment and the value of that outcome to the individual. One of the earliest users of expectancy models was Peterson (1974b), who explored the role of expectations and actually perceived conditions in the satisfactions of Boundary Waters Canoe Area recreationists. Roggenbuck (1975) used a similar approach to studying perceptions of whitewater river floaters in the backcountry of Dinosaur National Monument. Similar expectancy studies of whitewater floaters have been conducted in Desolation and Westwater Canyons in Utah (Schreyer and Nielson 1978) and on the Rio Grande River in Big Bend National Park (Graefe 1977). Rossman and Ulehla (1977) also explored the importance of wilderness environments for providing need-satisfying outcomes. Such studies underscored the significance of visitor expectations in influencing the wilderness experience, especially with regard to effects on the perception of objective conditions in the environment.

More recently, some researchers have attempted to use the more elaborate model of Fishbein and Ajzen (1975). This model includes a normative component in which behavioral intention is a function of the perceptions of significant others' expectations that a person should engage in a given behavior, and the individual's motivation to comply with the wishes of those other persons. This approach was used with limited success by Cockrell and McLaughlin (1979) to predict the environmental selections of whitewater river recreationists. While the complexity of the model has been a barrier to many researchers, the two areas of expectations and social norms have been major elements in research on understanding wilderness visitor attitudes and behavior.

General Motives.—Many studies have examined motives for participation in wilderness. Early studies were not geared toward a standardized measure of motive but asked visitors why they had chosen a given area. For instance, Bultena and Taves (1961) found Quetico Provincial Park visitors seeking opportunities to struggle with the elements, to get away from artificial settings, to explore, and to gain new experiences and personal gratification through realizing one's full capabilities. Most visitors were fishing, but the major rationale for visiting appeared to be not so much to catch fish as to be in a primitive and undisturbed area.

Lucas' classic study of Boundary Waters Canoe Area users (1964b) showed that people visited the area for reasons of solitude, to be with members of one's group, to learn about the area, and to commune with nature. Catton (1969) generalized about wilderness motives, particularly in terms of variations across different types of users. For instance, mountain climbers sought the opportunity to act in the face of uncertainty of success. In contrast, easy-access campers appeared to be seeking freedom from tension, from responsibility for the consequences of one's actions, and from parental duties. Catton noted that the desire for social interaction was often a strong motivator for participation, but so was privacy. Finally, Catton suggested that wilderness is valued for the "intellectual puzzles" that nature presents, which is why more highly educated people might be attracted to wilderness.

Although it would be possible to generate long lists of motives from numerous studies, it seems more useful to pursue generalizable consistencies in observations. One motive traditionally associated with wilderness use is solitude. While solitude is a part of the wilderness concept as defined by Congress, research indicates that the concept is not simple to interpret. Persons seeking solitude may likely be in the presence of others but seeking seclusion, anonymity (Twight and others 1981), or shared intimacy (Lee 1977). Hammitt (1982) found four dimensions to the concept of solitude in wilderness: natural environment, cognitive freedom, intimacy, and individualism. In a related effort, Hammitt and Brown (1984) found five dimensions related to the pursuit of privacy in wilderness: emotional release, personal autonomy, reflective thought, personal distance, and intimacy. It appears that what is generally described as solitude really covers a number of motives.

While people value sharing the wilderness experience with others, this is not a reason for wilderness participation as such. The social dimension is something that goes across the range of recreation participation and is not unique to the wilderness experience. Research on wilderness motives tends to show that although social reasons are often cited, they are generally less important than other motives (Shafer and Mietz 1969; Rossman and Ulehla 1977; Feingold 1979; Brown and Haas 1980). Similarly, although the escape motive is strong in wilderness participation, escapism is also a motive for other outdoor recreation activities (Driver and Knopf 1976).

Another dimension reported regularly in studies on wilderness is one that would appear to be obvious: appreciation of the natural environment. Beyond the nature experience and the pursuit of solitude, few other dimensions of motivation appear to be shared as consistently across studies (Kaplan and Talbot 1983).

While we seek common reasons for wilderness participation, we are aware there is considerable diversity in the reasons held by visitors. We next review the factors underlying these differences. First, we examine motivations linked to the type of activity pursued; people can have very different reasons for pursuing different types of activities, even though they all take place in a wilderness setting. Next, we examine differences across patterns of participation. We then look at the influence of the individual's background characteristics on motivation for participation. There are also potential combinations of motives for participation and these are also reviewed. Finally, we will look at how visitors to different wilderness settings vary in their motives.

Activity-Centered Motives.—The activity most strongly linked to wilderness participation is hiking. Lucas (1971) suggested that esthetic values—the enjoyment of scenery and contact with nature—were the most important motives for participation, exceeding exercise, socializing, or specific activities. He also noted that the esthetic response was more emotional or romantic than intellectual or educational. Temporary escape was seen to be a major theme.

Studies on hikers carried out in the East (Bowley 1979; Knopf 1983) and West (Brown and Haas 1980; Haas and others 1980b) tend to reflect similar results. Wellman and others (1982) identified significant differences in the rated importance by hikers of certain motives in Shenandoah National Park and park managers' predictions of those motives. The importance of motives to meet and observe new people, to learn and experience nature, to enjoy scenery, to reflect on personal values, and to express creativity is often underestimated. Thus, it might not be enough to observe that a motive is present. Rather, it is important to note the relative intensity of that motive (Brown and Haas 1980).

Bultena and Klessig (1969) provided a conceptual overview of the satisfactions derived from camping. They claimed that motives pointed toward benefits that could be derived specifically from the resource, rather than from mere change of pace or setting. They also argued that camping emphasizes the primitive, an "activistic" orientation, the search for a personal experience, and intrinsic rather than status-oriented goals. In a study oriented specifically toward the motives of campers, Hollender (1977) found important factors to be "primitive lifestyle," escape from responsibilities, esthetics of the natural environment, and escape from urban stress.

Motives for fishing have been explored in wildland settings (Driver and Cooksey 1977). Studies typically reveal that psychological motives are more important than the specific product pursued; that is, anglers seek the opportunity to relax, achieve, and socialize more than they value the fish (Knopf and others 1973; Kennedy and Brown 1976; Hendee and others 1977; Manfredo and others 1978; Knopf 1983).

Studies of hunters echo similar themes. More (1973) showed that hunters value the display of equipment, the desire to be outdoors, shared experiences with companions, escape, and challenge. Display of game and the enjoyment of eating it were also important. Other studies have shown the importance of escape, exercise, and companionship, and the lesser importance of actually harvesting game (Hautaluoma and Brown 1978; Hautaluoma and others 1982).

More specialized activities, such as cross-country skiing (Haas and others 1980a) and mountain climbing (Ewert 1984), have also been examined. Perhaps the most widely studied specialized activity is whitewater river floating. Roggenbuck (1975) and Schreyer and others (1976) found that the most important factors for floaters in Dinosaur National Monument were action/excitement, learning about nature, stress release/solitude, and affiliation. Similar results were found on the Rio Grande River in Big Bend National Park by Graefe (1977) and Ditton and others (1981), and in Desolation and Westwater Canyons in Utah by Schreyer and Nielson (1978). The motive studies on rivers invariably show outcomes similar to terrestrial situations, with the addition of motives related to action and excitement reflecting the whitewater component.

Finally, some studies have attempted to compare motives across different types of users of the same environment. Bassett and others (1972) compared the motives of trout fishermen and canoeists. In perhaps the most elaborate comparison of different types of users, Brown (1981) compared motives among backpackers, hikers, campers, fishermen, hunters, river runners, and cross-country skiers. He showed that motives common to all were relationships with nature, escape from social pressures, and being with one's recreation group.

In summary, although there are differences across activities in terms of specific motives or the relative intensity with which motives are held, there is nonetheless considerable agreement among visitors about the reasons for wilderness participation.

Patterns of Participation and Motivation.—It is likely persons with different motives pursue wilderness recreation in different ways. Roggenbuck (1975) and Schreyer and others (1976) compared persons floating the Green and Yampa Rivers through Dinosaur National Monument who exhibited different trip characteristics: day to overnight users, paddle trips to oar-powered trips, and commercial to private and educational trips. In each case, significant differences in motivation were noted.

Similarly, Ditton (1979) compared the motives of local to nonlocal floaters on the Buffalo National River and found significant differences in virtually all cases. Hammitt and Loy (1982) compared winter to summer visitors to the backcountry of Great Smoky Mountains National Park. They found winter visitors sought to avoid summer crowds and experience the winter environment.

Background Characteristics and Motivation.—Differences in motivation resulting in different patterns of participation in the same activity can be seen as the result of variation in background characteristics of the individual. For instance, Driver and Knopf (1976) linked differences in intensity of motivation to personality attributes.

A person's attitude toward the environment is another source of variation in motivation. Schreyer and others (1981) asked visitors to the backcountry of Canyonlands National Park whether they came because they liked the park itself, or because it was a good place to do their favorite activity. Significant differences were found between the two types of visitors in their motives for participation: those who liked the park itself were more interested in general learning and less interested in social recognition, testing one's skills, stimulation, being with friends, or tension release, than those who visited the park to pursue their favorite activity.

One background characteristic that has been explored in some detail is the amount of previous experience an individual has had in the activity. This variable has been used primarily with respect to whitewater river floaters; however, other types of wilderness participation have been similarly studied. McCool and Haydock (1976) examined differences in motives of hikers of the Virgin River Narrows in Zion National Park, based on differences in amount of experience. They found that experienced users tend to value escape more, and are less strong in their desire for action or excitement.

Differences in motive intensity related to previous experience have been shown in river settings by Roggenbuck (1975) and Schreyer and others (1976) in Dinosaur National Monument, in Desolation and Westwater Canyons in Utah (Schreyer and Nielson 1978), and on the Buffalo National River (Ditton 1981). In addition to intensity of motive, Schreyer (1982) showed there were differences in the specificity with which river runners stated their reasons for participation. Experienced users tended to be more detailed and specific in stating their expectations.

Previous experience can be defined in different ways. Schreyer and Lime (1984) showed that differences in motivation depended on whether experience was measured on the particular river being floated or experience in river running in general. To characterize the nature of this complexity, Schreyer and others (1984) created a six-category measure of "experience use history" to represent previous participation on the study river, on rivers in general, and the total number of different rivers run. Persons in the different categories showed different motive profiles for engaging in the activity.

Clusters of Motives.—Many motives influence the decision to participate in wilderness recreation. They vary considerably in relative intensity. To deal with this complexity more efficiently, researchers have attempted to classify people by shared groups of motives. Bowley (1979) distinguished two types of users based on differences in motives for affiliation, arousal, escape, and self-awareness. Using a clustering routine, Haas (1979) identified five "experience types" among hikers in three Colorado wilderness areas. Manfredo (1979) used a similar approach to identify three different experience types in wilderness areas in Wyoming. The fact that these studies identified different numbers of types illustrates the complexity in variation of motivation. Although people can share similarities in motivation, it is unlikely that specific, discrete "types" of wilderness recreationists can be defined.

Setting Types.—We assume that recreationists select different settings in which to pursue wilderness recreation because different motives for participation require different types of environments to fulfill perceived needs (Driver and Brown 1978). Thus, if one were to study different wilderness environments, variation in the relative importance of different motives for participation would be expected.

Haas (1979) compared types of backpackers, as mentioned above, across the Weminuche, Rawah, and Eagles Nest Wildernesses in Colorado. Having created five experience types for each area (a total of 15), he found that 10 of the types were unique to the various areas, while two were common across all areas and another was common across two areas. In contrast, Brown (1981) compared the motives of hikers, fishermen, and wilderness backpackers in the East and the West. While some differences emerged, the participants were more alike than different in motive profiles.

Williams and Schreyer (1981) compared the motives of visitors to the High Uintas Wilderness in Utah to those of visitors to the backcountry of Canyonlands National Park, also in Utah. The former area is characterized by alpine settings, while the latter is desert/canyon topography. Visitors to the desert placed more importance on tension release, competence testing, escape, and family togetherness than their counterparts in the mountains.

In river settings, Schreyer and Nielson (1978) compared the motives of floaters in Desolation Canyon on the Green River and Westwater Canyon on the Colorado River, both in Utah. While studies show statistically significant differences in the motives of recreationists in different settings, there is some question as to how big those differences really are. Knopf and others (1983) compared the motives of floaters on 11 different rivers across the Nation. They concluded that while differences across the rivers were noted, the motive profiles were more similar than they were different.

In summary, a variety of motives underlie wilderness recreation participation. Many of these motives are linked to opportunities typically associated with wilderness, such as the desire for escape and solitude, appreciation of esthetics and naturalness, and challenge and risk taking. Others, however, are less integrally associated with wilderness: meeting and observing others, making new friends, and various status-related motives are important for many visitors. Although typically less prominent than the former, these latter motives help improve our understanding of the "why" of wilderness participation.

Research also suggests that our conceptions of motives may often be oversimplified, particularly when we try to translate them directly into guidelines for management. Solitude is an excellent example; frequently cited as a measure of intergroup contact, it is in fact a complex construct that involves a variety of measures people use to regulate access to themselves (Altman 1975). Depending on its specific conceptualization, definition of the relevant measure and its implications for wilderness management will vary greatly. It seems likely that other motives share similar complexity and that our present conceptions of them are bound by limitations inherent to our measurement instruments.

Multiple motives underlie most participation. A behavior is engaged in to satisfy a number of wants. Variations in the specific motives identified will vary by individual, place, and activity. Over the population, however, the collective package of motives identified in research is most striking in terms of its similarity rather than its difference. The relative ranking assigned specific motives varies, but the constituent motives remain relatively consistent.

What does appear to vary is the intensity and specificity with which motives are identified. Factors such as previous wilderness experience probably help shape more rigorous conceptions of motives as well as produce greater intensity of support for them.

Finally, the motives identified by wilderness participants are often those identified by other types of recreationists. Our ability to distinguish recreationists by motives is limited. It may prove more useful to focus efforts on identifying variations in the intensity with which motives are held and the specificity with which they are defined, perhaps along with clearer articulation of the clusters of motives identified by different wilderness user groups, than in attempting to identify wilderness-specific motives that predict participation.

Decision Making and Participation

Given a certain set of motives, an individual must decide what type of behavior is most likely to fulfill his or her needs. The person can choose recreation, wilderness participation, and a particular environment and set of activities. To understand the forces leading to certain types of behavior and demands for wilderness opportunities, it is necessary to understand the factors influencing the decision process.

Decision Theories.—Early models of choice behavior tended to focus on information processing. Knopf and Driver (1972) and Driver and Brown (1975) adopted a problem-solving approach to recreation choice behavior. Individuals were seen as examining alternatives that would most rationally result in fulfillment of their needs. Thus, a high correspondence between the environment chosen and the need state of the individual was expected.

Haas (1979) examined multiattribute choice models from the consumer choice literature, but ultimately used the expectancy-valence model (Lawler 1973) to examine wilderness preferences. A comprehensive examination of recreationists' decision making has been performed by Krumpe and McLaughlin (1982). They reviewed the literature on choice models, including compensatory models, noncompensatory models, and elimination-by-aspects models, then suggested that recreation choice behavior could be best represented as a constraint-driven, conditional, sequential, elimination-by-attributes model (also see Stankey and McCool 1985).

The model proposed is untested, though McLaughlin and others (1982) did present information that floaters on different river segments vary in their perceptions of the desired attributes of the rivers. Applications of theories of choice have been incomplete. For instance, Cockrell and McLaughlin (1979) were not able to predict choice of a recreation environment using a test of the Fishbein and Ajzen approach (1975). Although not testing the entire Fishbein/Ajzen model, Manfredo (1979) did provide support for a link between basic attitude orientations of wilderness users and their support for various managerial actions. Harris (1982) suggested that different hikers might actually use different decision-making algorithms.

Factors Influencing Decisions.—Many of the factors influencing the decision to participate in wilderness recreation have little to do with wilderness as such. The availability of time, money, or access are all barriers. Many of Krumpe and McLaughlin's (1982) constraining attributes are situational concerns; they assert these will influence the decision to participate before the more positive attributes of an environment will affect choice. One major factor constraining decisions is likely to be the amount of information available to the individual making the choice (Stynes 1982).

Indirectly, data on background characteristics and use patterns of users support these contentions. For instance, wilderness users are predominantly from regions close to the wilderness and a large proportion of use is not for long periods of time (Stankey 1971a; Hendee and others 1978). Thus, constraints of time and distance could serve as barriers to participation.

Social influences exert considerable pressure on the individual. Thus, a person may be influenced by family or friends in the choice of an environment in which to recreate. Knopp and Leatherberry (1982) suggested that collective decision making can influence the information available to an individual choosing to participate. However, Cockrell and McLaughlin (1982) suggested that those most likely to be influenced by social forces are inexperienced participants.

The most common type of group is families, comprising half of all participants, while formal organization members vary from 2 to 10 percent (Hendee and others 1978). Schreyer and Nielson (1978) found that the most common reason river runners gave for going on the trip was that others were already going. Further, allegiance to a group for recreation purposes can be strong. When Schreyer and Downing (1980) asked backcountry visitors to Canyonlands National Park how often they recreated with the persons they were currently with, 46 percent said "frequently."

One factor that can influence the desire to participate is the classification of wilderness itself. Some people have expressed concern that when areas are formally designated as wilderness, they become more visible to the public and are perceived as more desirable as a recreation destination. Becker (1981b) provided indirect support that designations such as Wild or Scenic River increased the perceived desirability of the environment. However, McCool (1985) presented evidence that formal designation of Montana's Rattlesnake Wilderness did little to change participation in the area.

We see participation in wilderness recreation largely as the simple, straightforward desire of people to be in a wilderness. Nevertheless, people might end up in a wilderness because their friends are going, because the area is nearby and easily accessible, or because they simply are not aware of alternative environments in which to recreate.

Attributes and Participation

The previous section concluded that people visit different wilderness environments to fulfill different needs. This suggests that attributes of the environment are important in the decision to participate; they can facilitate or hinder the fulfillment of these needs. Given that such behavior might serve to guide development of an inventory for classifying different recreation environments (Buist and

Hoots 1982), a growing amount of research has examined the attributes of wilderness environments seen as desirable by recreationists.

One earlier attempt to assess attributes important to the wilderness experience was carried out by Peterson (1974b). He had Boundary Waters Canoe Area visitors rate 90 attributes on the desirability of their presence. Undesirable overperformers (things more common than desired) tended to be most commonly identified.

McDonough (1982) found that characteristics of recreation places were important in people's decisions to participate, but that the types of attributes that were important changed with the type of activity. Thus, it was not possible to standardize the aspects of recreation places found important. McLaughlin and others (1982) identified differences in environmental characteristics for six distinct river segments in the Flathead River complex in Montana. They concluded that the segments, though related geographically and used for the same activity (river running), had varying characteristics sought by recreationists for different experiences.

McLaughlin and Paradice (1980) compared the physical, social, and managerial attribute preferences of Idaho cross-country skiers and snowmobilers. They attempted to look at the desired experiences of the users, and concluded that some attributes may be more activity dependent than experience dependent.

The previously discussed motive typology studies have taken user groups and compared them using sets of attributes (Allen 1979). Manfredo (1979) compared his three motive types on 17 groups of attributes and found differences across the types on seven of them. In a somewhat different approach, Haas (1979) used discriminant analysis to see how attributes might predict experience types. He found five resource-attribute-discriminant functions, though the ability of the functions to discriminate among his five experience types was only on the order of 16 to 28 percent.

As an alternative approach to these methods, Watson (1984) employed a microcomputer selection strategy that had people rate desired preferences and then select areas based on the presence of the desired attributes. He wanted to see if a sequential decision process might be modeled through the computer program. Results indicated that in fact there was little correspondence between respondent ratings of attributes for wilderness environments and their subsequent selection of those environments. It is possible that people give more weight to certain attributes in making a decision than they do when rating their desirability individually.

Another approach used by Beaulieu and Schreyer (1982) provided respondents with an open-ended listing of desired attributes, rather than a set list. They compared visitors to mountain and desert wilderness environments, as well as those with differing amounts of experience. Attributes were classed into 16 different categories and ultimately reduced to four—physical, social-psychological, managerial, and activity. Significant differences were noted in the type of attribute and the mix of attributes named by respondents (Beaulieu 1983). Further, a comparison of onsite visitors with persons contacted at home and asked to make a hypothetical decision for participation also showed significant differences in the attributes identified (Beaulieu and Schreyer 1985).

Attribute research has consistently shown differences in preferences across activity, environment, and desired experience. However, there is no standardized list of attributes related to participation. Each study remains an idiosyncratic listing of setting features. Future research needs to be able to identify those attributes most consistently related to the behavior of wilderness recreationists.

Summary

What motivates a person to visit wilderness? Obviously there are many reasons, and they tend to vary among individuals as well as within individuals over time. A person visiting wilderness likely is there for a variety of reasons, many of which might have little to do with the fact that the area is indeed a wilderness.

Motives for visiting wilderness have been measured in many different ways throughout the years, though there has been an increasing movement toward more rigor and generalizability in both measurement and analysis. Motives initiate action; they form the basis for decisions to engage in certain behaviors. As a result, we engage in those behaviors expecting to attain the outcomes that originally motivated them. These expectations form a frame of reference against which we gauge our satisfaction with the experience. They might be more important in determining our enjoyment than actual objective features of the environment.

The most commonly cited reasons for participation in wilderness are solitude and to experience nature. Other reasons commonly mentioned are escape and social experience. It should be noted that none of these reasons is exclusively dependent on a wilderness to be realized. Rather, people perceive wilderness as a good place to attain these outcomes. Specific motives such as escape and social experience do not induce people to visit wilderness as such. They more often tend to come as a consequence of the overall experience.

While many motives are shared, others are not. Further, the relative importance of motives can vary considerably. Variations are a function of the type of activity people engage in, their patterns of participation (length of trip, mode of transportation), the environments they are in, and the background characteristics of the individuals themselves, such as the amount of previous recreation experience they have had. Many other ancillary factors, such as social group influences, proximity to a wilderness, and the formal designation of the area as wilderness, can affect the actual decision to participate.

Recent research has recognized the complexity inherent in motivation by attempting multivariate analyses of visitors' motives. This has resulted in the creation of "types" of wilderness visitors based on combinations of motives. However, these types have generally been idiosyncratic to specific studies.

There has also been an increasing effort to link various motives to preferences for specific attributes in the wilderness environment. This line of research is of growing practical significance in the planning and inventory of opportunities for different types of desired experiences. Again, this research is in an early stage, and the results of studies often have been difficult to interpret or generalize. However, the complexity inherent in motivation and in preference for various settings represents a challenge that can direct future research.

FACTORS AFFECTING VISITOR BEHAVIOR

Once a person has decided to visit wilderness, many kinds of behavior can be exhibited and many types of experiences obtained. This section is devoted to understanding factors affecting visitors while in wilderness. The first part will examine the psychological response of the individual to the environment and attempt to characterize the nature of the wilderness experience, as well as visitor perceptions of those environments. We then look at factors influencing patterns of participation in wilderness.

The Wilderness Experience

In the last section we talked of attributes of environments as they related to the desire to participate. The individual, however, is not a passive reactor to elements of the environment. Because people bring images and expectations with them, there is the tendency to filter attributes through mental conceptions of wilderness. To understand wilderness behavior, we must be able to view wilderness through the eyes of the visitor (Knopf 1983).

The way a person perceives the environment involves a subjective experience influenced by a collection of individual factors such as cultural and social forces, need state, and life history. Given the complexity of all the factors involved, we can never really know another person's experience; the best we can do is to express, through language, what appear to be shared perceptions.

Such expressions are particularly tentative when referring to environments that contain many symbolic elements of human emotion and values, such as wilderness. Even so, people talk of the wilderness experience as though it were a tangible and widely shared concept. What then constitutes that experience?

The wilderness experience represents a feeling ostensibly unique to wilderness. Essentially, we perceive relatively natural environments, then add cultural and personal meaning (Schreyer 1981).

The values of wilderness have been described in the popular literature by advocates of the concept. Although not empirically based, they represent shared meanings of the purpose of wilderness. Empirical support does exist for these values in more recent literature on motives and psychological outcomes.

Common themes in many popular writings emphasize "nature appreciation, education, freedom, solitude, simplicity, as well as spiritual, esthetic, and mystical dimensions of the wilderness experience" (Hendee and others 1978). Many of the early wilderness advocates echoed particular themes. John Muir wrote heavily of spiritual values (Wolfe 1938), while Robert Marshall characterized esthetic qualities (Marshall 1930). Aldo Leopold supported wilderness as a place to maintain unique recreational opportunities (Leopold 1925), while Sigurd Olson described the wilderness experience as one of insight and personal peace (Olson 1956). Arthur Carhart saw wilderness as a place for mental and moral restoration (Carhart 1955). Wallace Stegner claimed that the wilderness experience helped define our personal consciousness by serving as a frame of reference for our daily lives (ORRRC 1962). Many times, there is no clear distinction between what constitutes a wilderness experience and the values derived from experiencing wilderness.

Tuan (1974) maintained that the wilderness experience derives its meaning strongly from the urban experience: "Attitudes toward wilderness...insofar as they are verbalized and known, are sophisticated responses to environment that have their origins in the city. They presuppose the existence and recognition of environmental types and a degree of freedom to choose among them" (p. 248). Kaplan and Talbot (1983) maintained that, while much work has been done on various values associated with wilderness, there has been little research concerning what constitutes the fundamental and distinguishing nature of the wilderness experience. On the other hand, Frissell and Stankey (1972) assumed it would be possible to define a "pristine wilderness experience," a construct including "encountering no other people on a visit, the opportunity to witness completely undisturbed ecosystems, and so forth."

Scott (1974), in reviewing the works of a number of authors, claimed that a sense of "enhanced perception" was a common theme. Similarly, Hammitt (1982) maintained that a major aspect of the wilderness experience is that it affords a particular state of attention in which the individual is not required to attend to elements not considered to be a primary part of the experience. This is facilitated through the concept of "solitude" or "privacy" (Hammitt and Brown 1984); social expectations for interaction may be one of the strongest forces for distraction.

It is likely there is no such thing as **the** wilderness experience in terms of objective criteria. Knopf (1983) pointed out the many ways in which people can experience the same environment depending on their frame of reference. A given campsite can be seen as being either too secluded or too crowded depending on the expectations of the visitor (Foster and Jackson 1979). If visitors are seeking different types of experiences, they will likely feel differently about what they encounter.

Further, perception of the environment can be affected by the extent of differentiation a person makes. Some might see one wilderness as similar to another, while others obtain different feelings in different life zones or drainages in the same wilderness. How does the formal designation of wilderness affect the type of experience a person is likely to gain there? Would the same state of mind exist if the area were merely an unclassified roadless area (Schreyer 1980; Knopf 1983)? Reed (1973) showed that people's affective responses to hypothetical environments differed depending on whether they were labeled "National Park," "National Forest," or "State Park."

A major influence on perception is previous experience. A person might feel more affiliation with an environment through previous experience (Tuan 1974; Williams 1980), and evaluate the environment through many more subjective and symbolic values. Visitors to a new environment might evaluate what they encounter as normal (Heberlein 1977), while those who are experienced will evaluate the same scene in the context of what they have experienced before (Schreyer and others 1976; Nielsen and others 1977).

Images that people possess of an environment, whether experienced personally or not, will affect their behavior and perceptions in the environment (Knopf 1983). Such images often have little to do with objective reality (Hunt 1975). Rather, they are subject to shaping through marketing or through cultural myths and values (Lee 1972; Schreyer and Roggenbuck 1980). It is apparent that the experience of wilderness is likely to be highly personalized. Thus, much of the discussion of wilderness focuses on the individual's subjective state.

Wilderness Experience as Subjective State

Characterizing Subjectivity.—In essence, the wilderness experience can be characterized as whatever we are experiencing when we feel we are in wilderness; as such, it is not subject to objective measurement. Further, Knopf (1983) suggested that the way in which we conceptualize such environments is colored by our disciplinary backgrounds (for example, psychology, sociology, or resource management).

This need not constrain us from understanding the nature of things experienced. Given there is no absolute definition, it becomes a challenge to characterize the dimensions or features people use to describe what they feel.

Roderick Nash has been a consistent proponent of the fact that wilderness is "all in your mind" (1982). This emphasis has, in fact, been a strong underpinning to the notion that one does not have to visit wilderness to experience it. "Knowledge value" of wilderness suggests the experience goes beyond the bounds of the legally defined area.

This subjective meaning of wilderness is tied not just to the environment itself, but also to the context within which we define it. According to Tuan (1974, p. 112): "By the time we can speak of preserving and protecting wilderness, it has already lost much of its meaning.... 'Wilderness' is now a symbol of the orderly processes of nature. As a state of mind, true wilderness exists only in the great sprawling cities."

A wilderness experience depends on the person's perception of an environment. Thus, researchers have increasingly involved cognitive psychology to describe responses to environments. Kaplan (1977) described two basic types of attention, voluntary and involuntary. Many of the attractions of natural environments appear to be those that focus strongly on involuntary attention, capturing the attention of the individual with little effort or notice (Driver and Greene 1977). Attractions that fascinate or arouse us involuntarily fall into this category.

Voluntary attention, on the other hand, is much more active. This can be demanding and result in a need to return to a more casual and passive involuntary state. Hammitt (1982) claimed that wilderness solitude represents pursuit of a state of involuntary attention. However, a key is that the person controls the conditions under which that involuntary attention is exercised; one does not have to worry about the necessity to respond to a series of unrelated demands, such as social pressure. Hammitt (1984) maintained that this ability to attend to what one wants reduces the "cognitive cost" to humans, performing a restorative function for the individual. In research on the perceived values of wilderness environments, he reported that two elements seen as being particularly important were "resting the mind from anxiety and mental fatigue," and "promoting a sense of tranquility and peacefulness."

Subjective experiences are also characterized by emotion or effect. Many descriptions of wilderness experiences are characterized by altered states of mind in which strong emotions are felt. For instance, Scott (1974) described an "illusion" experienced by George Catlin through concentrating on a map of North America, in which he saw himself floating over the continent and witnessing the destruction of the bison. The emotional impact of this experience resulted in his vision of creating National Parks. According to Scott, "The episode can be described as a self-induced altered state of consciousness characterized by depersonalization, hallucinations, altered time sense, an intense feeling state, oceanic yet simultaneously detailed perception of environmental wholeness, intuitive intellectual insight, and a resultant prophetic proposal."

Thus, the wilderness experience has cognitive and affective components that interact to produce the experience. Ulrich (1983) developed a model of the relationship of effect to perception. He asserted that a person's initial effective state will influence the perception of the natural environment, and that the effective reaction to that environment will affect cognition or interpretation of what is seen, degree of sensory arousal, and future behavior. In some cases, this effect can serve to intensify and enhance the experience for the individual, and can be translated into action. According to Ulrich, "A wilderness backpacker who is fatigued might feel exhilaration or elation upon viewing an aesthetically spectacular setting, and these effects would produce physiological arousal and help to sustain his journey" (Ulrich 1983, p. 94).

Such states of restoration, effect, and arousal appear to help the individual attain higher states of awareness or self-consciousness (Scott 1974; Young and Crandall 1984) and improve the likelihood of attaining Maslow's (1968) level of "self-actualization," in which the person achieves a sense of personal fulfillment at the maximum level of human performance. The process of self-actualization is often characterized by "peak experiences," defined as situations in which the individual becomes egoless, where space and time become relatively insignificant, and the person's identity becomes merged with action and attainment of a greater sense of the whole environment.

Scott (1974) claimed that the most prominent wilderness writers, such as Muir, Catlin, Thoreau, and Leopold, used terminology closely linked to these concepts. He suggested that wilderness environments catalyzed their personal self-actualization. In making the argument that such environments promoted self-actualization, he cautioned against assuming that **only** such environments or experiences did so. Rather, he was claiming, much like Hammitt (1984), that such environments were particularly rich in characteristics that foster such states. The wilderness experience can promote altered states of consciousness and awareness, but it shares this quality with other forms of human experience, such as art and religion.

In perhaps the only empirical test of such relationships, Young and Crandall (1984) concluded that wilderness users were more self-actualized than nonusers. Frequent wilderness users, however, were no more self-actualized than nonfrequent users, and the strength of the relationship between wilderness use and self-actualization was concluded to be weak.

The Religious/Spiritual Experience.—When focus moves toward altered states of consciousness and extreme conditions of effect, wilderness experiences appear similar to mystical, spiritual, or religious types of experiences. This is strongly rooted in the philosophical writing about nature by early wilderness advocates, and the linking of nature with the transcendental experience by writers such as Thoreau.

John Muir considered "wild nature" the conductor of divinity, and believed that wilderness should exist as a source of free-flowing psychic and spiritual energy (Nash 1982). Arthur Carhart (1920, p. 20) felt that "the individual with any soul cannot live long in the presence of towering mountains or sweeping plains without getting a little of the high moral standards of nature infused into his being." Joseph Wood Krutch (1958, p. 275) stated, "Wilderness and the idea of wilderness is one of the permanent homes of the human spirit." Roggenbuck and others (1973) used the philosophy of Sigurd Olson to express the long-term notion of spiritual impact of the wilderness experience:

> They think they go into the back country for a lark, just to test themselves or to face a challenge, but what they really go for is to experience the spiritual values of wilderness.... It may take years for them to realize what they found, but sooner or later it will come back to them.... (Olson 1969, p. 137)

Much of the writing moves from the concept of the experience of wilderness itself to suggestions that the natural environment should be used as a source of inspiration for the development of human ethics (Churchill 1982; Douglas 1983). This belief has led to study of different religious or value systems such as Native American cultures (Callicott 1982; Erickson 1977), or Asian religions, such as Taoism (Ip 1983), Jainism, Buddhism, and Hinduism (Nash 1982), that are compatible with respect for nature. Tuan (1974) warned that any culture's stated ethos does not necessarily represent their actual behaviors toward the environment; many cultures espousing unified views of humans and nature nevertheless have participated in major environmental depredations.

Although most writings have been in the domain of the philosophical, there have been some attempts to take a more systematic look at the spiritual aspects of the wilderness experience. Scott (1974) used a framework of altered states of consciousness designed by Fischer (1971) to analyze the nature of the experience being described by the nature writers. Using this framework, Scott noted:

> ...the reverie of Catlin is a meditative state mediated by the parasympathetic component of the autonomic nervous system and the treetop adventure of Muir would be an ecstatic state resulting from stimulation of the sympathetic division of this system. Carl Jung...conceptualized self-development or "process of individuation" in much the same way as Maslow and used the term "archetype" to describe man's inherited unconscious complex of feelings, ideas and images. Jung personally received tremendous inspiration from nature and mountains and perceived in the latter an expression of man's potential. Wilderness experiences may involve the expression and reaffirmation of specific archetypes. (Scott 1974, p. 236)

Spirituality can encompass a broad range of human experiences. Some of this spirituality has been viewed in the context of a religious experience. Perhaps the most detailed analysis of the religious content in wilderness is Graber's monograph (1976). This work is more speculative than empirical, but it attempts to bridge the gap between religious and wilderness values. She noted that religious experience does not have "content," but rather is characterized by the subjective nature of human feelings toward certain objects, institutions, or ideas. Wilderness is essentially "sacred space," an environment toward which religious feelings are directed. Graber used the notion of "geopiety" to represent a broader feeling of "reverence, propitiation, affection and compassion" (Graber 1976, p. 5) directed toward the earth. In this sense, many religious feelings directed toward wilderness are really manifestations of broader ethical feelings about one's relationships with nature, in much the same way that a specific church is the vehicle for experiencing one's feelings about Christianity.

Graber drew analogies between wilderness purists and religious sects. Both represent a social order in which there is an accepted rhetoric and mode of behavior to reinforce the validity of the belief system. The imagery and content of the revered writers serve to direct one's perceptions in wilderness, so that one is attuned to seeing the "right" things, and thus becomes appropriately socialized to being able to have the religious experience of wilderness.

Graber asserted that religious connotations are hard to escape, even when segregated from one's personal religious feelings:

> The wilderness ethic is strongly religious in character. Wilderness is treated as sacred space by the community of purists, whether or not purists consciously accept the notion of wilderness as hierophany. (Edward) Abbey considers himself an atheist, Krutch was an agnostic, at one time (Ansel) Adams denied or apologized for the spiritual quality of his photographs; yet none of these artists can quite escape his own preoccupation with sacred power. If one believes that wilderness is a manifestation of sacred power...he gains a fixed point, or center, which stands out from the chaotic relativity of ordinary life. (Graber 1976, p. 11)

Graber argued that wilderness provides a source for religious experience because it is a focal point for human needs for order, for community, and for a unified image that can provide meaning. She asserted that the force of this feeling is catalyzed into political action by those affected. Much of this energy "stems from the ability of wilderness imagery to flow into the void left by the erosion of spiritual and aesthetic values associated with the countryside and city" (Graber 1976, p. 115). Whatever the mobilizing forces, it is apparent that because people perceive wilderness as an appropriate focus for the expression of religious feeling, this becomes part of a broader litany through which persons may learn to experience values that religions traditionally deliver: meaning, order, transcendence, communion.

Perceptions of Environments

Much of the previous section has dealt with the effective content of the wilderness experience. This section will focus more on the cognitive elements of wilderness: what people actually perceive as the object of the wilderness experience, and how that is given meaning in the mind. This will influence the set of attitudes people hold about wilderness.

Wilderness Purism.—It is virtually impossible to tap the full range of personal meanings of wilderness. Because it is subjective, many idiosyncratic components of knowledge and feeling will be involved. However, it may be possible to create some summary that may reflect these broad concepts. This has led to the attempt to develop attitude scales tapping people's concepts of wilderness.

The first effort to represent empirically the range of wilderness visitor attitudes was made in the Pacific Northwest by Hendee and others (1968). They created a set of 60 questions consisting of 20 items on liked or disliked features of wilderness, 20 on activities that might occur in wilderness, and 20 on benefits that might be obtained. Respondents were to rate the items on a scale from "strongly dislike" to "strongly favor." Persons who were at the purist end of the scale in terms of more extreme scores were labeled "wildernists," while those at the other end were labeled "urbanists" (Hendee and others 1968).

Responses to the scale were factor analyzed to explore the underlying dimensions of wilderness attitude. Of course, the selection of items in part predetermined the content and nature of the dimensions. They identified seven different dimensions of wilderness attitude: spartanism—the physical desire to encounter the environment in a challenging manner, antiartifactualism—the appreciation of the lack of signs of human development or activity, primevalism—the desire to experience a natural setting, humility, outdoorsmanship, aversion to social interaction, and escapism. Using the degree of association of items in the factors as a guide, a refined scale was then developed using only 30 of the items. This refined scale was subsequently used to compare wilderness users' perceptions toward appropriate behaviors and toward possible management strategies, and their background characteristics. They found wilderness purists to be young, highly educated, and predominantly from urban backgrounds, lending support to the notion that wilderness appreciation arises from an urban culture.

This concept of tapping the wilderness-attitude domain has been criticized as having somewhat questionable validity. There is the feeling that what is being measured is limited to the domain of the 30 items, which may be a very narrow expression of people's attitudes toward the wilderness experience (Copp 1967). Heberlein (1973) noted that any attempt to measure attitudes should recognize both the effect and belief components of attitudes. Further, there is a need to understand that attitudes are linked and interwoven in a complex manner. One must be able to account for the centrality of the attitude toward the object being studied and the relationship among the attitudes. Heberlein asserted that failure to consider these factors in the conceptualization of such an attitude scale limits the practical utility of its application.

Stankey (1971b) used a somewhat different approach to the measurement of wilderness attitude. He attempted to link the scale to the Wilderness Act with the rationale that because that legislation served as a constraint on, as well as a guide to, management of wilderness, attitudes should be defined in the context of the act. His scale consisted of 10 statements concerning three aspects of wilderness defined in the act: ecology, level of development, and simplicity of recreational activities. Four other items relating to the nature of the wilderness environment were also added. Respondents rated each item in terms of favorability on a five-point scale ranging from very desirable to very undesirable.

Persons were scored according to their answers ranging from 14 to a possible 70 points. Persons at the high end of the scale were labeled "strong purists" while those at the other end were "nonpurists." Stankey used this classification to examine differences in user perceptions of encounters with others (Stankey 1973). He argued that because purists were closest to the conception of wilderness held in the legislation governing these lands, managerial decisions about limiting use and protecting the environment should be geared toward the attitudes of persons who were closest to the spirit and intent of the legislation (Stankey 1972).

Wilderness purism scales have not achieved widespread utilization. Applications of the results from such scales might be hindered by the notion of "purist," which carries with it elitist connotations that run counter to more democratic notions of management. Schreyer and others (1976) developed a wildernism scale based on Stankey's approach. They developed an initial scale of 27 items and then used 17 to classify river floaters in Dinosaur National Monument. In order to avoid the potential semantic contamination of the purist label, persons scoring high on the scale were called "high wildernists." Differences in wildernism scores were linked to significant differences in visitor characteristics, motives for the trip, trip characteristics, perceptions of crowding, and evaluations of management strategies.

Rentz and Schreyer (1977) developed a multi-item "attitudes toward wilderness" construct in a study of wilderness hazard perception. They found that although the scale was positively related to previous exposure to general information about hazards, it was not related to perceptions of hazards independently. In a similar study, Williams and others (1984) found that prowilderness attitudes did relate to greater preparation and awareness of hazards among cross-country skiers.

Wilderness Attitudes and Perceptions.—Although it is difficult to tap the full domain of attitudes toward wilderness, it is much easier to identify specific attitudes and perceptions. One approach has been to ask people what elements characterize wilderness. A public opinion survey to test general public awareness of wilderness (Yankelovich, Skelly, and White, Inc. 1978) asked people what activities they felt were or were not permitted in wilderness. They did not define wilderness or make reference to legally designated areas, leaving that to the interpretation of the respondent.

Over half the public believed developed campgrounds with sanitary facilities were permitted, 42 percent believed sightseeing by car was permitted, 41 percent thought commercial harvesting of trees was permitted, and 32 percent thought motorcycling and jeeping were permitted. Although people might be disturbingly unclear about the exact properties of wilderness, it is notable that they have strong positive feelings for the concept. Eighty-three percent of the sample believed that the Federal Government has an obligation to save large areas of undeveloped land for wilderness preservation.

In an attempt to assess visitor perceptions of wilderness qualities, Schreyer and Nielson (1978) asked river floaters in Desolation and Westwater Canyons in Utah if they felt they had been in a wilderness while on the trip. Eighty percent of the sample indicated in the affirmative. Respondents were then asked when they felt the wilderness began (neither river is formally designated in wilderness status). For Desolation Canyon, nearly a third indicated it started while riding to the launch site, while another 15 percent indicated it started at the launch site.

Another approach has been to ask persons to describe what characterizes a particular environment for them. In a public opinion poll about attitudes toward the California Desert (not legal wilderness), the Field Research Corporation (1977) found that 62 percent of the respondents indicated beauty and nature, 54 percent said solitude, 42 percent identified freedom, and 34 percent said adventure. Beaulieu (1984) used an open-ended format to ask people for aspects of a wilderness environment that led to their desire to participate there. The largest proportion of respondents identified aspects of the psychological experience as most important. About 45 percent of respondents identified these elements, while only about a quarter of the respondents identified actual physical components of the environment.

Lucas (1964b) asked visitors to the Quetico-Superior area of Ontario and Minnesota about their perceptions of wilderness qualities, the area considered wilderness, and appropriate uses. Although there were substantial variations in response, most visitors had well-defined notions of what constitutes wilderness. Approximately three-fourths of the canoeists sampled identified wilderness qualities as a major reason for visiting the area (Lucas 1964a).

In assessing preferences of the public for wilderness conditions, Peterson and Lime (1973) cautioned against potential measurement bias. They provided evidence that nonresponse bias can affect the validity of data, and suggested that persons answering questions in the field might answer differently from persons answering at home. Beaulieu and Schreyer (1985), in a study of wilderness attribute preferences of persons onsite versus those at home, also found significant differences in response patterns.

One of the major components in the perception of wilderness qualities is the more general idea of the esthetics of natural environments. There is a vast literature on this subject that has been organized and reviewed elsewhere (Daniel and Vining 1983; Ulrich 1983). Worth noting, however, is an increasing tendency to move from evaluations of general landscape features to specific components of the environment, such as air quality (Daniel 1979) and the impact of sound on the experience (Kariel 1980; Anderson and others 1982). An important aspect of esthetic qualities is the extent to which they can be used to establish the value of a particular area. In this regard, Leopold (1969) used esthetic elements to characterize Hell's Canyon on the Snake River as a unique environment.

Perception and Satisfaction.—How do people evaluate wilderness? What makes them satisfied or dissatisfied with what they encounter? Because wilderness is a resource judged by subjective criteria, sources of satisfaction and dissatisfaction provide insights into what comprises the most appropriate definition of wilderness. Sources of dissatisfaction can provide managers with feedback indicating the extent to which they are providing desired wilderness conditions.

While it makes sense to measure satisfaction, research efforts to do so have not been highly successful. Global measures of satisfaction are often used, but these provide little in the way of useful information about a person's response to the many varied and complex aspects of the recreation environment (Probst and Lime 1982). Thus, there has been an increasing tendency to measure various aspects of satisfaction. For instance, Ditton (1979) used nine different statements related to satisfaction in surveying Buffalo River floaters.

Studies have looked at specific elements contributing to overall satisfaction, such as mode of travel (Shelby 1980a). Lucas (1980) looked at the degree of association between a number of elements of the trip and overall satisfaction for wilderness hikers, while Shelby and Nielsen (1975) did the same for river floaters. Peterson (1974b) used a similar though more detailed approach to evaluating sources of wilderness quality through the discrepancy between desired and actually encountered conditions. Other approaches to the subject have included measuring changes in the behavior of users in response to perceived conditions (Anderson 1980).

Because motives represent reasons why people visit wilderness, it stands to reason they would be related to satisfaction with conditions encountered. The importance of the motive is thus critical; if high, then we would anticipate a close correlation between the extent to which that motive is satisfied and the actual use conditions that foster its realization. If the motive, say solitude, is of low value, however, there might be little dissatisfaction with high levels of encounters (Stankey and McCool 1984).

McCool and Petersen (1982) linked types of sources of satisfaction and dissatisfaction to respondents' scores on various desired psychological outcomes. They argued, following Herzberg's (1976) two-factor theory of satisfaction, that separate conditions might produce satisfaction and dissatisfaction and that a condition whose presence leads to satisfaction might not result in dissatisfaction when absent; conversely, conditions producing dissatisfaction do not necessarily lead to satisfaction if absent.

One of the most important concerns addressed by this research is what factors are most important in contributing to visitor dissatisfaction. One of the most important sources of dissatisfaction—encounters with others—will be dealt with subsequently. Many other sources of dissatisfaction in wilderness are related to perceptions of impacts resulting from human use (Bultena and others 1981a). Studies generally focus on different dimensions of impacts. For instance, Lucas (1979) examined various environmental factors in three wilderness environments. Litter turned out to be the most commonly perceived negative impact.

McCool and Petersen's (1982) work on the two-factor notion found that some aspects of the environment served to act as satisfiers, enhancing the experience, while others were seen as dissatisfiers, detracting from the experience. The most commonly perceived dissatisfiers were related to encountering others. Other negative factors were litter (identified by 57 percent of respondents), insects (47 percent), and dogs (35 percent).

Some studies have looked at specific negative aspects. In a study of dispersed forest recreationists, Downing and Clark (1979) showed that 92 percent of managers felt litter was a serious problem, compared to 50 percent of visitors, though both identified it as their most commonly perceived problem. Ninety-one percent of managers felt vandalism was a serious problem, compared to only 37 percent of the visitors.

In a river setting, Shelby and Nielsen (1975) found that perceptions of use-related impacts correlated significantly with overall trip satisfaction on the Colorado River in the Grand Canyon. In a less pristine setting on the Upper Delaware River in New York, Dawson and others (1981, 1982) also found litter to be the most commonly perceived problem, though only 23 percent of their respondents listed it as a serious problem. In a study of Boundary Waters Canoe Area Wilderness canoeists, Anderson (1980) examined "negatively valued attributes" perceived at entry points and campsites as well as during the day one entered the wilderness. Seeing litter, having to camp at heavily used campsites, and seeing peeled bark on trees were among the most negative of perceived attributes.

As part of the National River Recreation Study, recreationists were asked to evaluate a comprehensive list of perceived problems (Knopf 1982). The most common problem was again litter, with 54 percent of all respondents across 38 different rivers indicating that it was at least a slight problem.

One concern about impact is the extent to which it might be changing. Lucas (1980) asked repeat visitors to nine wilderness areas whether conditions were getting better, worse, or were about the same. While roughly half the respondents indicated things were about the same, the proportion of persons who identified conditions as getting worse ranged from 20 to 37 percent.

Evaluations of impact can vary depending on the nature of the individual. For instance, Vaske and others (1980) showed that persons who had first visited an environment several years before tended to evaluate environmental conditions more negatively than those whose first visit occurred recently. Anderson (1980) showed differences in evaluations of impact across the four motive-profile types she created for the Boundary Waters.

Two major observations emerge from this research. First, visitor dissatisfaction may result as much from differences in individuals as it does from differences in the objective conditions in the environment. Variations in motivations and previous experience are significant influences on evaluations.

Second, the most commonly cited sources of dissatisfaction have to do with the presence of others or their perceived impacts. Litter is probably the single greatest negative factor encountered in a wilderness setting.

Influence of Information on Participation Patterns

To this point, we have examined factors that influence visitor attitudes, perceptions, and behaviors. Although many of these factors are inherent in the individual or the environment, others are a function of management. Managers often desire to influence visitor behaviors or perceptions, in order to maintain the quality of the environment or reduce problems causing visitor dissatisfaction.

One of the more common techniques for influencing visitor behavior is using information to aid visitors' decisions about such things as trails to hike or campsites to use. This can have a positive effect on the persons involved because they are more likely to find a place meeting their expectations. Further, it can serve as a management tool in helping to distribute use away from heavily impacted areas.

The distribution of information has been tied to other management strategies, such as the requirement for permits (Lime and Buchman 1974). Such permits can be a source of information that can be fed back to the visitor about use patterns and rates. Further, issuing a permit can serve as a source of contact with agency personnel, and an opportunity to give visitors information that might help disperse use (Magill 1974).

A growing body of research has developed from attempts to influence visitor behavior through the use of information. Although some successes have been noted, results are mixed, suggesting more sophisticated methods may be necessary. The primary focus of information research has been on redistributing use from heavily used sites to less impacted areas.

Use Distribution.—Schomaker (1975) found that information on "crowded areas" in Colorado's Rawah Wilderness handed out at the trailhead had no significant effect on travel route selection. A similar attempt to redistribute use through rules printed on required permits in the Great Gulf Wilderness of New Hampshire (Canon and others 1979) also failed to obtain significant results. Lucas (1981) attempted to redistribute use in the Selway-Bitterroot Wilderness through the use of brochures providing information on use levels of trails. Overall use patterns were not shifted toward lightly used trails. Such results have been blamed on information being given to visitors after the decision to use an area had already been made, suggesting that such information needs to be available earlier in the decision process.

In the Boundary Waters Canoe Area, persons with permits for heavily used entry points in 1974 were sent information packets before the 1975 season, providing information on use levels and alternative routes. Results showed about one-third of the respondents claimed the information influenced their travel plans for 1975 (Lime and Lucas 1977). Krumpe (1979) and Krumpe and Brown (1982) employed an experimental design in Yellowstone National Park to influence trail selection by providing persons with information about characteristics of various trails based on visitors' desired experiences. They found that 37 percent of the subjects selected one of the targeted trails. Hahn (1982) used a photographic decision-tree approach with visitors to the San Rafael Swell region of Utah before they made actual travel plans. She found that about a quarter of those who returned to the Swell actually used new areas targeted in the process.

Increasingly, research has attempted to do more than just give information to recreationists. One approach is to test the relative effect of different media for communication. Roggenbuck and Berrier (1981, 1982) tested the value of two different information media to distribute camping use in North Carolina's Shining Rock Wilderness. They used a brochure alone and in combination with a personal message. Both approaches resulted in redistribution of use, but neither was more effective than the other.

Appropriate Behaviors.—In addition to distributing use, information can affect the behavior of wilderness visitors. Because impact is a particular concern, development of behaviors likely to minimize impacts is a desirable goal. This can depend on previous learning on the part of the individual, or it may be a function of conscious efforts to give such information to visitors in a way likely to produce the desired behavior.

Fazio (1979a) suggested that a mandatory permit is a successful way to deliver information to wilderness visitors. There is the question as to which type of communication is most effective. In a test of backcountry hikers in Rocky Mountain National Park, Fazio and Gilbert (1974) used a brochure, slide show, and trailhead sign to inform hikers of appropriate behaviors. Only the slide show resulted in significant improvement in low-impact camping knowledge.

Different media can be more or less useful in getting to the visitor. In a study of Selway-Bitterroot visitors, Fazio (1979b) reported that the most commonly reported sources of information concerning appropriate behaviors were the Forest Service, "experience," and friends and relatives. McCool and Haydock (1976) found that the most common sources of information on safety behavior among Zion Narrows hikers were park rangers and warning signs.

Although it might be possible to identify sources of information, it is not clear just how effective they are. In a study of cross-country skiers in the Wasatch Mountains of Utah, Williams and others (1984) found that only 48 percent of skiers reported ever seeking out any information on avalanche hazards, and only 17 percent had sought out information on the day of their outing. Rentz and Schreyer (1977) underscored the importance of previous learning in showing that there was an **inverse** relationship between exposure to park information and preparation for natural hazards in Arches and Canyonlands National Parks.

To maximize effectiveness, some have attempted multimedia approaches. For instance, Matheny (1979) reported an attempt to reduce trail shortcutting through the use of signing, local school poster contests, and the use of mass media. The program, combined with experimental revegetation, was considered a success.

In recognition of the need to become more sophisticated in reaching audiences, researchers have adopted notions of "market segmentation." This approach is geared toward identifying persons most likely to be a source of concern, studying their characteristics, and then targeting information strategies directly toward them. For instance, Matheny (1979) identified 13- to 17-year-olds as the group most likely to engage in shortcutting. Consequently, special school education programs were targeted toward them. Robertson (1982) found several factors significantly related to appropriate behavior in wilderness, including knowledge of behaviors, attitude, education, and age. Fazio (1979b) reported on studies of the knowledge of wilderness users in Rocky Mountain National Park and the Selway-Bitterroot Wilderness. He found cross-country hikers and technical climbers to be more knowledgeable than day hikers in Rocky Mountain National Park. In the Selway-Bitterroot he found outfitters and group leaders to be more knowledgeable than hunters, day users, pilots, or horse campers. Thus, if one wants to be effective in reaching people, it might be useful to attempt to reach persons with the least amount of knowledge.

Role of Education in Influencing Behavior

Information can be seen as a passive way of influencing behavior, while education is a more active approach. There is a belief that education will not only create a greater appreciation of wilderness, but will increase demand for such environments (Hendee and Roggenbuck 1984). A more common notion of wilderness education is the use of a field experience in which the individual confronts the forces of nature. Such programs, often described as "high adventure" or Outward Bound types of experiences, are deemed to have long-term beneficial effects on the individual, not only in terms of appreciation of the wilderness environment, but in the self-concept that has benefited from challenging nature.

Many studies have been performed on these types of programs, and the literature has been summarized elsewhere (Meier and others 1980; Kaplan and Talbot 1983; Kaplan 1984). Although much attention has been directed to this topic, results are not particularly straightforward. A number of studies describe both immediate and long-term changes in participants (Thorstenson and Heaps 1973; Heaps and Thorstenson 1974; Kaplan 1974; Thorstenson and others 1975). Other studies are less positive. Gillette (1979), in a study of attitude changes resulting from participation in an Outward Bound program, found significant changes in only 15 percent of the items measured. In a test of potential changes in anxiety levels of participants in both an adventure program and in a leadership experience, Chesnutt (1982) found neither long- nor short-term changes.

It appears that approaches to this line of research will have to be more standardized and systematic to establish generalizable conclusions concerning the effects of such programs. Programs differ significantly in clientele, course content, duration, and intensity. Measures vary from attitudes to personality dimensions to actual behaviors. In this sense, it is often difficult to know who is doing what to whom.

Social Influences on Behavior

Any attempt to understand the nature of human behavior in a wilderness setting must account for social influences on behavior. Because most visitors enter wilderness in groups (Cheek and others 1976; Lee 1977), the wilderness visitor is enmeshed in a social context that strongly defines the recreation experience (Cheek and Burch 1976; Knopf 1983).

Social groups have been identified as a major influence on recreation participation (Field and O'Leary 1973; Field and Cheek 1974; Hammitt and McDonald 1982). Such social considerations might be more important in predicting behavior than the activity, as that behavior might be keyed to the group dynamics of the situation (O'Leary and others 1974; Field 1976). Participation can be the result of the desirability of social interaction itself. Social learning can affect people's preferences for participation, as evidenced by the influence of activities learned as a child on adult preferences (Yoesting and Burkhead 1973). Hendee and others (1968) found that nearly 70 percent of wilderness users made their first visit to a wilderness before the age of 15. Further, indirect factors such as stage in the family life cycle can affect preferences for different types of activities. For instance, Burch (1966) found that remote-camping families were most likely to be those just starting a family or older families in which the children were leaving home.

Many social forces are at work to influence an individual. Cockrell and McLaughlin (1982) outlined ways in which social influences operate on wild river recreationists. They suggested that such forces shape beliefs about the desirability of various activities, the motives for participation, and through direct social influence on participation. Social group influences can be an important force in shaping members' behaviors (Sessoms and Stevenson 1981). Further, the mechanics of the group composition, such as party size (Lime 1972), can affect behavior patterns.

As a part of a specific cultural group or lifestyle, individuals identify certain activities or behaviors as being appropriate to demonstrate that lifestyle. Thus, rates of visitation to National Parks are generally higher among middle class communities than working class communities (Bultena and Field 1978, 1980). In many cases, recreational activities are seen as defining the lifestyle, and unique "social worlds" can evolve (Devall 1976).

Persons acting in a group have a notion of appropriate behavior within the group. Such social roles might be specific to a given situation. However, Burch (1965) suggested that activities carried out in forest settings show considerable overlap to roles played out in daily life. To the extent that people feel certain behaviors are appropriate, they are responding to shared norms of the group.

Such norms might be global perspectives on how lands such as wilderness should be managed or used. In their study of wilderness users in the Pacific Northwest, Hendee and others (1968) identified five clusters of norms about appropriate behaviors shared by visitors: responsibility and equity, rejection of controls on behavior, withdrawal from the symbols of civilization, maintenance of unpolluted campsites, and camping skills. This survey was conducted at the beginning of the environmental movement; given that use pressures and controls have shifted dramatically since, it would be interesting to see whether a replication would yield the same dimensions of norms.

In his study of wilderness "purism," Stankey (1971b) used measures of visitors' attitudes on levels and types of use of the wilderness, as well as preferences for management alternatives. These values became the rhetoric of purism. Graber (1976) asserted that "wilderness purists" have a definite "ethic" of behaviors that should be exhibited. In a sense, this defines membership in the class of purists. One identifies oneself not just by one's attitudes, but by one's behaviors.

Social forces can affect the meaning of a given place, determining the behaviors judged appropriate within the environment. Lee (1972) suggested that a major factor influencing behaviors in remote settings is the image of the place shared by social groups and their conceptions of appropriate behaviors keyed to that definition. Schreyer and Roggenbuck (1980) suggested that shared meanings of places can be global and affect specific behaviors only in a very general sense. In support of this notion, Schreyer and White (1979) showed that park visitors' definitions of the meaning and purpose of National Parks were unrelated to their evaluations of the appropriateness of certain nontraditional recreation activities. Rather, evaluations were more linked to an individual's participation in the activity; if he or she participated in the activity, he or she was more likely to consider it appropriate.

Social forces can also affect a person's perception of the experience itself. It is possible that group sentiments reinforce individual evaluations of satisfaction, in a sort of "aren't we having a good time!" fashion. Lime (1977) suggested that persons with considerable experience, such as commercial outfitters on whitewater float trips, can exert considerable influence over the experience for visitors. Influence can range from enhancing visitor perception through interpretation to increasing visitor arousal by creating illusions (for example, that rapids are larger and more dangerous than they really are).

Evolution in Behavior

The forces influencing wilderness behavior are dynamic. As a result, the notions of what constitutes appropriate behaviors also evolve. Some of this evolution is in response to use pressure. For instance, the norm in rock climbing has moved to "clean" climbing rather than traditional methods such as the use of pitons and other more permanently defacing techniques. Technology has had an impact as well. Lightweight, portable cooking sources are not only common, but in many cases required. The traditional wilderness experience of cutting pine branches for one's bed and sitting around a large campfire in the evening has been replaced with minimum-impact camping techniques. Even where such behaviors are not required by agency personnel, they can become part of a norm used to assess the legitimacy of an individual's presence in wilderness.

The evolution of technologies has led to controversy over the extent to which certain activities are appropriate. For example, are hang-gliders appropriate in wilderness? It can be argued that few activities are closer to representing harmony between user and environment. Does the technology involved represent the trappings of civilization any more than a lightweight backpack or tent? Is the visual intrusion any more offensive than the sound and contrails of a 747 passing overhead? Such questions force us to confront both the perceptual and legal conceptions of what really represents wilderness; continual evolution of technologies is likely to continue, particularly if there is a market supporting research and product development (White and others 1980).

There has also been an evolution in the nature of experiences sought in wilderness. A growing number of persons are using such environments to actively seek risk (Schreyer and others 1978). Wilderness environments can be very challenging, and persons seeking to experience risk find them attractive for such encounters. Many reasons have been advanced for why people seek to put themselves at risk. They range from stress-seeking personalities (Klausner 1968) to physiological chemistry of the brain (Zuckerman and others 1972) to neurotic death wishes. Schreyer and White (1979) suggested that risk involves a situation in which a person gains immediate feedback about performance and is required to behave in a way that requires optimal use of skills and abilities. This leads to feelings of self-determination, achievement, and a sense of perceptual focusing on the activity, resulting in a greater sense of awareness and heightened personal insight.

Summary

Wilderness is an objective reality composed of physical objects in the environment. What makes those objects "wilderness," however, depends on our personal feeling about such environments. In this sense, it is a very subjective concept. Our image of wilderness is likely influenced by our values, beliefs, emotions, previous experiences, exposure to information, social influences, and even our fantasies. These subjective images affect what we consider wilderness, whether we decide to visit it, and what we experience when we are actually there.

Public perception of wilderness is very positive when the general population has been surveyed. There is tremendous variation, however, in what people actually consider wilderness to be. People also vary strongly in their intensity of feelings toward the value of wilderness. This range of intensity has been measured by various researchers as "wilderness purism" or "wildernism." Such value systems have been linked to attitudes toward wilderness preservation, management, and appropriate behaviors while in wilderness.

The frame of reference people carry into the wilderness affects their perception of and experience in wilderness. While anyone can have some kind of experience in environments labeled as wilderness, much research has focused on "the wilderness experience" itself. This wilderness experience does appear to be tangible and valid, but it is very idiosyncratic, and depends on individual needs and images. There is more to it, however, than just saying "people are different." There are, in fact, commonalities underlying the idiosyncracy. This is because the elements of perception involved are generalizable to other aspects of human experience, especially extreme states of consciousness.

One point of commonality is that persons tend to describe the wilderness experience in terms of enhanced states of perception or awareness. Another element is the tendency to describe such experiences in mystical, spiritual, or religious terms. Persons who have studied these experiences find that the subjective feelings described are very similar to those found in studies of the religious experience in general.

It is helpful to think of wilderness as serving as a catalyst for persons seeking a state of altered consciousness. In this sense, the wilderness does not "give" the person the wilderness experience, so much as it serves as a vehicle for such perceptions. This is a function of setting conditions in which such perceptual focusing is possible, a set of beliefs within the person that such states are desirable (people generally do not have either wilderness experiences or religious experiences if they do not consider them desirable, although people may attain such states without consciously aspiring to them), and a belief that such settings are likely to produce such experiences. In the same sense, a church does not give a person a religious experience; rather, it is seen as a place in which such an experience appropriately occurs. Also, as in a church, social reinforcement may help a person attain such experiences.

It is important to emphasize that such experiences are tangible and perceived as real. Further, the outcomes of such experiences in wilderness are essentially the same as those of a religious experience: a sense of meaning, order, transcendence, and communion.

What makes a person satisfied with what is encountered in the wilderness setting? This is a complex topic, as satisfaction is a multidimensional concept. Many elements go into a determination of satisfaction. However, research has consistently shown that the two most commonly cited sources of dissatisfaction are the presence of others and evidence of human impacts, especially litter. The evaluation of the presence of others is variable across settings and persons. The presence of litter, however, is among those most consistently recognized negative impacts across the range of research examined.

Many factors affect people's perceptions of wilderness and their behavior while in the environment. Some of these are amount and type of previous experience, information previously exposed to, background characteristics, social group forces, one's emotional state, and the environment itself. People are not static entities, and their behavior patterns can change over time. Such changes can be a function of evolution in technology or in the conditions in the environment, through changes in the person's life cycle, and changes in the types of experiences sought, such as the growing desire to experience challenge and risk.

There is an increasing tendency to study what influences visitor behavior, with the intent to affect behavior for management considerations. For instance, social group forces have been shown to be very important in influencing norms of appropriate behavior. If such forces could be tapped, they would be very powerful vehicles for behavioral compliance.

The area of behavioral influence that has been most studied is the use of information. Attempts have been made to use information to encourage visitors to stay away from more heavily used areas and to adopt appropriate behaviors, such as minimum-impact practices or taking precautions against natural hazards. The results of such studies have been mixed, suggesting there might be more to influencing human behavior than just giving people information. These considerations should form the basis for future research efforts. Indirect means of managing people in wilderness are of growing importance.

Questions of appropriate behaviors and administrative response to calls for different types of opportunities suggest that the notion of wilderness management is challenging. One of the other papers in this collection deals specifically with the notion of wilderness management (Brown and others this proceedings). We recognize that an important input into decisions about what management strategies to use is the attitudes of visitors toward those management strategies and it is to this topic we next turn.

ATTITUDES TOWARD WILDERNESS MANAGEMENT

Many studies have been conducted on the attitudes of wilderness visitors toward various management actions. In some situations these actions have been planned; in others they have already been implemented and visitors are responding to their presence. The studies cover a period of over two decades, and there have been some major shifts in opinion about management as there have been in attitudes toward wilderness in this country.

One of the most important sets of attitudes visitors possess deals with the management of wilderness.

Managers seek information on visitor attitudes toward management actions for a variety of reasons. Will visitors support a change in management or do they support the current program? How strongly do they feel about some proposed action? Which segments of the public are supportive of some action and which are opposed? All of these are legitimate issues that managers might seek input on from attitude studies. Data on visitor attitudes, however, need to be put in the context of the other factors that influence decisions.

We need to stress that attitudes are not a prescription for management. Laws and policies might often dictate certain actions that are not popular. In these cases, managers can use attitude information to help reveal potential dissatisfaction, thereby alerting them to the need for programs that explain the rationale for such actions. Such efforts might not change the opinions people have concerning the action but could increase their knowledge and lessen the chance of conflict.

In other cases, people's attitudes are based on poor or incomplete information about the management action and fail to account for consequences that might be detrimental to wilderness values. To follow such attitudes irrespective of these outcomes would be irresponsible. At the same time, a knowledge of these attitudes would be helpful in designing programs that upgrade visitor understanding.

Because attitudes predict behavior only partially, managers need to be careful about placing excessive reliance on attitudes as a guide for management. Even where strong opinion about some matter is registered, it is still possible that visitor behavior might not reflect the expressed attitude. This is particularly the case in situations where the attitudes are expressed in general terms; most research literature points to the typically low predictability of such attitudes for estimating behavior (Wicker 1969). Heberlein and Black (1976) demonstrated that as the specificity of attitude scales increased from general environmentalism to measures of personal norms of nonpolluting behavior, so did the correlations between the scales and behavior. However, the authors also noted that general attitudes remain important foci for study; they influence a wide range of specific beliefs and, indirectly, a number of behaviors.

While there are limitations to the use of attitudes by wilderness managers, we want to emphasize strongly that the systematic review of visitor attitudes is essential for effective management. Numerous studies point to the differences that exist between managers and visitors about a whole range of concerns (Hendee and Harris 1970; Peterson 1974a). Often the views of visitors differ significantly from those held by area managers, and it is important that these differences be clearly understood. In some cases the views of visitors will offer viable alternatives to managers. In those cases where manager perspectives prevail, it is important that effective programs identifying the rationale and basis for decisions be formulated.

Systematic attitude surveys also provide a means of balancing the selective perception that affects us all. Wilderness visitor surveys reveal a diverse body of opinion; not all visitors want facilities or oppose restrictions. The experiences that managers have in dealing with visitors can sometimes contribute to generalized conceptions about what visitors want or oppose that are simply inaccurate (Hendee and Pyle 1971). Systematic feedback on attitudes helps counter these misconceptions, thereby avoiding actions based on imagined concerns.

In the following review, we will examine the attitudes of visitors toward four broad areas of concern: management of environmental conditions, management of trails and access, management of campsites and facilities, and management of visitor use.

Management of Environmental Conditions

Today, we largely take for granted the general condition of wilderness and appropriate uses and activities, in part because of the definition embodied in the Wilderness Act. But it is important to remember just how recent this codified definition is and how differing conceptions characterized the situation only a few years ago. The question of the appropriateness of resource exploitation activities, the control of fire or insects and diseases, or the role of active intervention in ecological processes was, less than three decades ago, something about which there was a great deal of diversity.

A brief review of some of the findings of Outdoor Recreation Resources Review Commission (ORRRC) Study Report 3 (1962) reminds us of this diversity of opinion as well as the crystallization of the wilderness concept as we know it today. The survey included visitors to the Mount Marcy area in the New York Adirondack Forest Preserve, the Boundary Waters Canoe Area in Minnesota, and a portion of California's High Sierra, including parts of Yosemite and Sequoia-Kings Canyon National Parks and the High Sierra Primitive Area.

The study provided clear evidence that most users considered wilderness as a place where exploitative activities should be limited. Between two-thirds and 85 percent felt wilderness should be left untouched and that resources, such as timber and minerals, in wilderness should not be utilized. Yet, from 16 to 34 percent were undecided or felt such resources should be utilized.

Respondents were also queried as to whether humans should try to control and manage wildlife and vegetation in wilderness or whether natural forces should be allowed to proceed with minimum interference. Again, the predominant response was in favor of the minimal interference approach; between 60 and 80 percent of the respondents preferred to let nature run its course. Nevertheless, between 20 and 35 percent indicated that control and management should be exercised.

These data indicate that scarcely two decades ago there was a significant minority view among wilderness visitors that such areas should be open to traditional resource development activities and that active environmental management was appropriate. As we continue this review, the dramatic shifts in opinion on these issues will become apparent. Yet they remind us of the constantly evolving nature of our conception of wilderness and the likelihood such conceptions will continue to change.

Even after passage of the Wilderness Act, ambivalence about management of the environment persisted. Hendee and others (1968) asked visitors to three wildernesses in the Pacific Northwest a series of questions about the appropriateness of selected resource management activities in such areas. Virtually all felt that human-caused fires and outbreaks of nonnative insects or diseases should be controlled as quickly as possible; nine out of 10 disagreed with the idea of allowing natural events, such as lightning-caused fires and infestations of native insects or diseases, to run their course; and a similar proportion supported the idea of artificial restoration of areas denuded by fire, insects, or disease.

These early data suggest that the conception of wilderness held by many visitors consisted of two parts. At one level, there was a general consensus that wilderness was a place of natural conditions where normal management activities were inappropriate. However, at a second level, there was a tendency to support intervention to control the outbreak of natural forces such as fire—a position that contradicted the more general level of support for minimum interference, but that was consistent with a conception of wilderness as a place of recreation and scenic beauty. This contrast between the general and the specific attitudes held by wilderness visitors is characteristic of attitudes in other domains. It is also reflective of a particular time in history; the concept of wilderness in the late 1950's and early 1960's was evolving and consolidating. The exact nature of those areas that were to be wilderness was not agreed upon, and the diversity of opinion, particularly at the specific level, reflects the different, often conflicting, views that existed at that time.

In the ensuing years, the conception of wilderness, especially within agencies, has taken on more specific form. Much of this specificity was shaped by the Wilderness Act itself; timber harvesting, for example, is simply not permitted. Moreover, the idea of wilderness as a place where natural forces predominate, where human intervention is the exception rather than the rule, has come to have greater acceptance. Consequently, our review of the literature did not reveal any recent studies that examined attitudes toward such issues of environmental management as insects or diseases. However, a major public policy issue concerns the role of fire in wilderness. A review of the shifting pattern of attitudes toward fire will help illustrate how rapidly such dispositions can shift, as well as indicate their relationship to the decision process.

Fire.—Although the Wilderness Act contains authority for the control of fire, it was recognized early that fire was perhaps the dominant force shaping the vegetative mosaic in many areas. Years of successful suppression had altered the natural successional process greatly, and it was clear that if such areas were to be areas where historical ecological processes operated substantially beyond human control, our attitudes toward fire and the expression of the attitudes in terms of organizational policy needed to change. Since passage of the Wilderness Act, we have seen an evolution from complete fire suppression to planned fires in some areas to help restore earlier disturbances.

Few other forces have played such a major role in giving form to wilderness. Moreover, few other environmental forces produce such deep emotional responses among the public. The fear of fire and its impacts, both environmental and economic, helped generate development of fire control policies and technologies that have brought fire under substantial control over the past 60 years.

Increasingly, however, there has been recognition that the control of fire in wilderness is contrary to the objectives of protecting natural ecological processes. Consequently, there has been a progressive switch from fire control to fire management. With this policy move, increased attention has been devoted to public attitudes. This is a relatively recent phenomenon; early studies of wilderness fire. For example, the ORRRC (1962) provided no direct data regarding attitudes about fire suppression policy, but did note that between 70 and 93 percent of persons sampled in seven areas felt trees should be replanted in burned areas within wilderness. Hendee and others (1968) investigated three wilderness fire-related items in their work on three Pacific Northwest wildernesses. Ninety-eight percent of respondents felt human-caused fires in wildernesslike areas should be put out immediately, 95 percent felt lightning fires should not be allowed to run their course, and 90 percent felt wildernesslike areas denuded by fire should be restored as soon as possible.

As interest in allowing fire a more natural role in wilderness ecosystems grew, more research attention on public attitudes toward fire occurred. Lucas (1980), reporting on his 1972 surveys of visitors to nine wildernesses and other roadless areas, found between 15 and 30 percent favored a natural fire policy, about one-third were neutral, and between 40 and 60 percent thought such a policy undesirable. In a 1982 followup in three of the previously studied areas, he found that support had reached nearly 50 percent, with less than one-third opposed (Lucas 1985). Visitor attitudes toward fire had clearly become more favorable.

Stankey (1976) studied the relationship between the attitudes that Selway-Bitterroot Wilderness users held about fire management and a number of other variables, including age, education, wilderness experience, and the respondent's score on a test of fire knowledge. He found that a policy of no suppression was rejected by most respondents, but 43 percent also rejected complete suppression. Overall, suppression was favored.

There was a strong relationship between the attitudes toward wilderness fire policy and knowledge of fire effects. As test scores rose, so did the likelihood the respondents would favor a modified suppression policy. A gamma of 0.57 was found between the test score and the number of times that policy was selected as "most acceptable." The more people knew about fire, the more they favored a policy of restoring a more natural role to fire.

The data from the Stankey study were collected in 1971, at a time when modified wilderness fire suppression was just becoming a major public concern. Later, McCool and Stankey (1986) repeated the study, using the same methodology, with visitors to the Selway-Bitterroot Wilderness. The average score on the fire knowledge test rose 11 percentage points, from 53 percent to 64 percent in the period. Moreover, there was a nearly 50 percent decline in 1982 in the percentage of individuals scoring in the very lowest category and a major increase in the percentage scoring in the highest two categories.

There was also a corresponding shift in attitudes toward appropriate fire suppression policies. In 1971, 56 percent of the users questioned favored a fire suppression approach. The 1984 study indicated that only about 17 percent favored these policies and only 5 percent supported complete suppression. Interestingly, only a very small percentage in either year supported a policy of completely letting all fires burn, suggesting that visitors remain unwilling to support extreme positions. Over 70 percent of the 1984 sample supported a policy of allowing some fires to burn in wilderness.

tudes toward the use of scheduled prescribed fire or fire ignited by managers in wilderness according to an approved fire prescription. Nearly 50 percent felt that such scheduled prescribed fire would be beneficial while slightly more than one-third indicated they were "unsure." Only 16 percent felt that such fires would be detrimental. Of those aware of the practice of prescribed fire outside wilderness, 27 percent were unsure of the effects of scheduled prescribed fire in wilderness. This is in contrast to those who were unaware of prescribed burning; 51 percent were unsure of the effects of scheduled prescribed fire in wilderness.

Management of Trails and Access

Trail systems are a primary influence on the movement of recreationists in a wilderness. They also have the potential to affect a visitor's experience in either positive or negative ways. Thus, trail management is an important component of wilderness management.

Trails are, by definition, impacts on the environment. In some areas, the lack of trails would make travel difficult if not impossible. Elsewhere, cross-country travel can be undertaken with little trail development. Trails are especially important for certain types of use, such as horseback travel.

But while trails are impacts that are generally acceptable and expected, it is clear there are limits to the nature and extensiveness of their development, the standards to which they are built, and the locations in which they are placed. Many trails that cross wilderness areas are a product of the period of major fire control and were intended to move people and equipment from one point to another quickly and efficiently; they were not designed to move people through a wilderness with minimum impact, or improve the quality of their experience.

A number of studies report visitor attitudes toward trails. Hendee and others (1968) summarized these attitudes, noting "Trails should be developed and maintained appropriate for the use received—of varied quality and not of uniformly high standard throughout wilderness-type areas." However, they also found little support for very low-standard trails (blazed routes) and even less support for trails surfaced with sawdust or woodchips to control dust.

Stankey (1973) found mixed opinion about appropriate trail standards. The response to providing more high-quality trails (no further definition was given) was evenly mixed among those favoring, those rejecting, and those neutral to such an action. Like Hendee and others (1968), he found that those users classified as being more purist in their wilderness orientation tended to be less supportive of high-standard trails. Among visitors to Idaho's Salmon River, Tarbet and others (1977) reported strong support for low-standard trails and leaving fallen trees across trails. This support appears particularly linked to the role of such practices in controlling access. Visitors appear to recognize that the quality of access can have an effect on the amount of use an area receives; the question as to what is an appropriate level of development for trails becomes enmeshed in the question of how access will affect the use of an area.

This concern with the effects of access on the use of an area surfaced in a study by Stankey (1980) comparing use in a lightly used wilderness in the Northern Rockies with use in a heavily used wilderness in California. In both areas, about half the respondents favored reducing the number of trails and the blocking of access roads back from the wilderness boundary as a way of controlling use. Again, it is possible to interpret these results as reflecting a particular disposition toward access into the area or as a way of controlling use other than direct regulation. The data do suggest that visitors recognize the important role access plays both in the amount of use an area receives and the distribution of that use. Lucas (1964b) found little support for the idea of straightening or blacktopping roads leading to the Boundary Waters Canoe Area—further evidence of the recognition by visitors that such developments can alter greatly the nature of use in an area.

Murray (1974) queried Appalachian Trail users as to their attitudes toward two possible trail management practices, including side trails to bypass rough or steep sections and marking trail sections as to their difficulty. In both cases, approximately three out of four respondents said they favored these steps or that it didn't matter. Those hikers with the most experience tended to differ slightly from others, being less favorable to both actions.

Echelberger and Moeller (1977) found that visitors to the Cranberry Backcountry in West Virginia were predominantly in favor of what they had; about four out of 10 said "don't change" when asked about adding more foot trails and providing areas with no trails. One-third did support more foot trails, but fewer than 20 percent favored the addition of areas with no trails. This status quo position is not unlike the response of many people about proposed changes in familiar settings. Womble and others (1978), in a study of hikers on Alaska's Chilkoot Trail, found many specific comments about the trail and its condition, but the predominant message was "keep the Trail as is."

A knowledge of trends in attitudes toward trail conditions is generally lacking. One important exception is found in data reported by Lucas (1985). His analysis revealed that between 1970 and 1982 in the Bob Marshall Wilderness complex in western Montana, support for high-standard trails, defined as wide, with steady grades and fairly straight, grew significantly (table 1). Complaints about trail conditions grew sharply in the 12-year period, becoming one of the major responses given by visitors to a question regarding perceived changes in the area. The support for high-standard trails is in contrast to the general support expressed by visitors for a more primitive, undeveloped approach to management. This is likely due to the severe deterioration in trail conditions in much of the area. Visitors traveling on horseback were more in favor of high-standard trails than were backpackers; the reverse was true for low-standard trails, defined as being somewhat like a game trail—narrow, grade varies, winding, not the shortest route. Over the study period, however, support for low-standard trails appears to have diminished slightly.

Trailless areas were strongly supported by respondents in the Lucas study and there was little change over the study period; 70 percent in 1970 and 73 percent in 1982 supported such areas and there was little difference between horseback and foot travelers.

The construction of bridges is another access-related issue. Different arguments are raised regarding such structures, but typically matters such as public safety and effects on use distribution are cited. In those studies where questions about bridges have been raised, the pattern appears to be one of public support. Stankey (1973) found that nearly two out of three persons favored the construction of wood bridges across wide rivers; safety is likely a factor in this response. Those visitors classified as more purist tended to be less supportive. Echelberger and Moeller (1977) found that Cranberry Backcountry users were split on the issue of bridges, with nearly half content with the current situation, but another third wanting more.

Again, Lucas (1985) noted a shift in attitude toward bridges over the period 1970-82, with the general trend toward increasing support. In response to an item "bridges over rivers that are dangerous for hikers to wade or for horses to ford," support rose from a four to one margin in 1970 to over seven to one in 1982. Support also grew for bridges over small creeks where one could get wet feet.

Signs represent an important component of the wilderness access system. Hendee and others (1968) examined a number of questions about signs. The overall conclusion was that people preferred wood signs, showing directions only (as opposed to interpretive messages), located at trail junctions rather than concentrated at trailheads. Those users classified as more purist showed a slight tendency to support the preferences expressed by the largest percentage of other users. The authors also noted that most ques-

Table 1.—Visitor opinions of high and low standard trails, 1970 and 1982 (source: Lucas 1985, p. 29)

Year	High standard				Low standard			
	Desirable		Neutral	Undesirable	Desirable		Neutral	Undesirable
	Percentage of total visits							
1970	45		23	33	63		22	15
1982	A[1]	B			A	B		
	32 ± 3	40 ± 4	12 ± 3	16 ± 2	52 ± 4	7 ± 2	23 ± 4	18 ± 3

[1] In 1982, there were two possible desirable responses—A, "desirable," and B, "desirable in more heavily used parts of wilderness, but not in more lightly used parts."

tions produced a fairly large neutral response, ranging from 30 to 40 percent, suggesting a lack of clearcut opinions or simply that signs were of little importance.

Tarbet and others (1977) also found a lack of clear opinion with regard to signs among users on the Salmon River. The mean scores on four items related to signing all clustered on the neutral rating (an overall mean of 2.1 on a 3-point scale). The authors observed that experience likely plays a major role here; they note "infrequent users are likely to approve of these management techniques while frequent users might be opposed."

Lucas (1985) found that opinion about interpretive signs onsite shifted sharply over the period 1970 to 1982. While such signs were opposed by a two to one margin in 1970, they were favored by a small margin in 1982. Support was inversely related to experience; novices were supportive of such signs while experienced users were opposed.

The lack of signs marking trails was a major concern of visitors to the Linville Gorge and Joyce Kilmer/Slickrock Wildernesses (Roggenbuck and others 1982). Although problems with signing ranked among the top 10 as perceived by users, only about a fourth of the visitors, in fact, described it as a problem.

In summarizing attitudes toward trails and access, several points can be made. First, visitors want adequate access that accommodates their style of travel; muddy bogs are not adequate transportation networks for hikers or horseback travelers. Second, a diversity of trails is needed to accommodate different styles of travel as well as different experiences. For example, there is support for trailless portions in most areas but there is also support for areas of trail development. Third, much of the concern with trail systems does not focus on the extent of the system (indeed, there is support for maintaining what there is in most studies), but with the maintenance of that system. Finally, trails are perceived by virtually all visitors as an appropriate and necessary feature of the wilderness setting; bridges are also considered in keeping with the area's designation.

Adequate signing, including basic directional information, appears to be considered appropriate to most visitors. Moreover, the Lucas data (1985) suggest that even limited interpretive signing is not unacceptable to many. Under current Forest Service policy, these latter types of signs are prohibited; only signs providing routing information are permitted. Consequently, other types of information need to be provided by other means, such as maps or brochures. We will look at attitudes toward these techniques subsequently.

Management of Campsites and Facilities

Campsites are a particularly important aspect of visitors' images of wilderness settings. For overnight visitors they represent locations where many of the wilderness values that prompted the visit are enjoyed. Because they are the foci of use, they receive a great deal of management attention; thus, important questions of appropriate development arise. In this section we review the findings of a number of studies that examined visitor attitudes toward campsite development and associated facilities such as toilets, corrals, and firerings.

Stankey (1973) asked visitors to three western wildernesses and the Boundary Waters Canoe Area (BWCA) if they favored more campsites. Only about 20 percent of those in the western areas favored this action. In the BWCA, nearly half of the respondents were in favor of such a step. The difference appeared related to the generally wide availability of sites in the West as opposed to the more constrained situation in the BWCA.

Echelberger and Moeller (1977) found opinion evenly split on the provision of walk-in primitive campgrounds in the Cranberry Backcountry, with about a third in favor of adding more, another third saying "don't change," and the final third with no opinion.

In a study of backcountry users in Michigan's Sylvania Recreation Area, West (1981) found that among those visitors reporting they felt crowded, about 70 percent favored keeping the number of campsites at current levels and another 20 percent favored a decrease in the number. Among those who did not feel crowded, 81 percent felt the current number of campsites was satisfactory and only 3 percent favored a decrease.

Merriam and Ammons (1967) reported little support for simple campgrounds (defined as including tables, stoves, hitching racks, and outhouses) in either the Mission Mountains Primitive Area or the Bob Marshall Wilderness, but slightly over half the visitors to the wilderness backcountry of Glacier National Park supported such developments.

Among river runners in Dinosaur National Monument, Roggenbuck and Schreyer (1977) found that more users opposed than favored campsite development suggestions. Users were even more opposed to returning campsites to a more primitive or natural condition than to the proposed development, suggesting that existing sites and their condition are generally found satisfactory by users.

These limited data provide reasonably clear evidence that any appreciable effort to expand the number of wilderness campsites has little visitor support. From a management perspective, conducting inventories of potential sites could be useful as a means of reducing impact and crowding at existing sites; visitors might feel such efforts simply lead to more use. Also, the idea of providing more campsites in wilderness might conjure up images of car access style campgrounds that visitors see as inappropriate.

Toilets.—Toilet facilities are a concern in many areas. Problems of threats to human health and objectionable esthetics have led many to consider whether some type of installed toilet facility is desirable. ORRRC Study Report 3 (1962) initially pursued this matter, discovering wide-ranging opinion in their three study areas; 70 percent of visitors supported toilet facilities in Mount Marcy, 50 percent in the BWCA, but only 36 percent in the High Sierra. Shortly after the ORRRC study in the BWCA, Bultena and Taves (1961) reported that nearly 80 percent of the canoeists they interviewed there rated toilets as important.

Hendee and others (1968) found that about half of the respondents in their study supported toilet facilities in wilderness, but those rated more purist in attitude tended to strongly oppose such facilities.

Stankey (1973) found a variable pattern of support for toilets across the four study areas he investigated. Consistent with earlier findings, visitors to the BWCA were most supportive—nearly two-thirds favored placement of toilets. In the West, only about one-fourth of the visitors to the Bridger Wilderness and High Uinta Primitive Area favored toilets, but 43 percent of visitors to the Bob Marshall did. Two likely possibilities explain these results. First, the support for toilets is based on their perceived need. In the BWCA, for instance, the extensive water area and limited soil cover help contribute to concerns about pollution, particularly because most campsites are on lakeshores. Thus, toilets are seen as a way of controlling a potentially serious problem. Second, the presence of toilets (or other facility) likely contributes to acceptance; at the time the study was conducted, toilets were still commonly found in the Bob Marshall.

Lucas' trend study (1985) reported that while toilets were equally supported and opposed in 1970, opposition to them grew to a two to one margin by 1982. Womble and others (1978), however, reported that 80 percent of the hikers on the Chilkoot Trail felt toilets were an appropriate facility along the trail; it is likely hikers perceive the Chilkoot to be more of a "historic" trail than one traveled for its wilderness appeal. Schreyer and others (1976) also found that whitewater travelers saw toilets as appropriate, but preferred pit toilets to more developed restrooms. Again, visitor attitudes appear linked to site-specific characteristics and these make simple generalizations regarding support or opposition difficult.

Firerings and Fireplaces.—Other facilities that have attracted management concern are firerings and fireplaces. There are concerns that permanent firerings attract use; in many areas it is common practice for wilderness rangers to dismantle them with the idea that users will not always camp at the same location, thereby reducing site impact. On the other hand, there is concern that fires can lead to site impacts, such as soil sterilization (Cole and Dalle-Molle 1982) and that dispersing firerings will simply increase the aggregate area so affected.

A variety of studies have probed visitor attitudes toward firerings and fireplaces. Early studies (for example, Bultena and Taves 1961) suggested in general that such facilities were acceptable in wilderness. Lucas (1964b) found that canoeists in the BWCA favored movable firerings to iron and cement fireplaces. Hendee and others (1968) reported substantial opposition to permanent fireplaces in wilderness, particularly by purists; about 50 percent endorsed movable rock fireplaces, with the purists slightly more inclined to agree. Schreyer and others (1976) found that among river runners in Dinosaur National Monument, most were strongly opposed to a ban on open fires and strongly in favor of retaining fire grates; however, nearly one-half were opposed to requiring fire pans.

Lucas (1985) reported a fairly major shift in visitor attitude toward firerings and fireplaces. Whereas cemented rock fireplaces were opposed by a three to one margin in 1970, this had grown to four to one by 1982. Moreover, while loose rock firerings had been only narrowly favored in 1970, in 1982 they were favored by a 47 to 29 percent margin.

Results from research suggest that visitors find limited facilities for fire use appropriate and acceptable, with temporary firerings more acceptable than fireplaces. The practice of removing and scattering rocks from firerings probably does little to eliminate an unwanted impact from the visitor's perspective and might produce undesired environmental impacts.

Shelters.—Although typically prohibited in classified wilderness, permanent shelters do exist in many primitive, undeveloped areas; Washburne and Cole (1983) reported that 12 percent of the units in the National Wilderness Preservation System contain such developments. Some shelters have historical significance, but most are valued for their protection from the weather and, in some cases, wildlife. Hendee and others (1968) found that nearly 60 percent of visitors agreed that three-sided shelters for hikers were consistent with an area being wilderness, but purists showed a moderate tendency to oppose them. In Glacier National Park, nearly 80 percent of the respondents favored trail shelters, but in adjacent National Forest wildernesses, they were opposed by a majority (Merriam and Ammons 1967). On the Chilkoot Trail, nearly 85 percent of the hikers felt shelters were appropriate (Womble and others 1978). Again, the level of support for some action appears conditioned by the context in which it exists. Where they have existed previously or where there are mitigating circumstances that support their presence, visitor attitudes typically are supportive.

Stock Facilities.—A final type of facility includes developments related to stock use in wilderness and backcountry areas, including fences, corrals, hitching racks, and the like. Hendee and others (1968) reported a general pattern of opposition to such developments, typically with 40 to 50 percent expressing opposition and only 20 to 30 percent in favor. The fairly large block of remaining opinion was neutral, suggesting many people had either not thought about the issue sufficiently to form a position or were genuinely unable to express their view.

Stankey (1973) found fairly strong opposition to the provision of hitching racks and corrals; only 20 percent favored them and half were opposed. Even in the Bob Marshall, where horse use is common, only about 25 percent were in favor; interestingly, there was little difference in support between backpackers and horseback travelers. Lucas (1985), however, found a different pattern with regard to the provision of pole corrals at campsites; in 1970 they were favored by a four to three margin, while in 1982 they maintained a very narrow margin of support. In both years, horsemen were much more favorable toward such facilities than backpackers. The reason for the difference in the two studies' results is not clear, especially given the difference in support among horse users.

In summary, the pattern regarding campsites and associated facilities seems to suggest a trend toward support for more primitive, nonconvenience-oriented approaches. The appropriateness of any given facility seems tied to a clear recognition on the part of the user as to the need and rationale for the facility, and where this can be demonstrated support likely follows. Also, where a facility has existed previously, there tends to be more support for it than where it would represent a new addition to the setting. In both cases, any effort on the part of management to change the status quo will need to be paired with a major effort to communicate the reason for such a change; otherwise, public opposition will likely occur. Facilities geared to a particular class or type of user are typically supported by that user, but this is not always the case; in a horse use area, uniform support for a decision to allow pole corrals cannot be assumed.

The move to a more self-reliant, less convenience-oriented user probably has its roots in two areas: the growing availability of equipment that fosters independence (such as high-quality, self-contained petroleum stoves) and the many efforts by agencies and organizations to promote more independent styles of wilderness travel.

Management of Visitor Use

Much wilderness management involves the management of use. Lucas (1973) observed that the issue is not so much a matter of whether such management will occur, but rather a matter of how it will be implemented.

There are many specific approaches to managing wilderness use, but in this review we have organized the presentation along three lines: management of information; management of recreation behavior; and direct use limitations, including quotas and rationing.

Attitudes Toward Information as a Management Tool.—There is much interest among both managers and users as to the potential role of information and education as tools for management and as alternatives to regulation and control. In many areas, much of the future management task will be hinged on an improved program of information dispersal to visitors. Recently the Chief of the U.S. Forest Service defined the wilderness management challenge as being "80 to 90 percent education and information and 10 percent regulation" (Peterson 1985).

Visitors appear to agree. Most studies reveal a decided preference for those management actions involving information and education approaches. Roggenbuck and others (1982) found the most popular management strategy in three eastern wildernesses was the provision of better information on use; nine out of 10 respondents in each area favored this strategy. Stankey (1973) concluded from his study of users in four areas that actions influencing use in more subtle, discrete ways, such as through the use of maps, were rated more favorably by users than direct, heavy-handed techniques. For example, 50 to 60 percent of the users in all areas were supportive of better maps and information pamphlets, with purists slightly less so inclined, possibly because of concerns that such information might increase use in the area.

Another source of information is the wilderness ranger program. Although these people have many duties, informing visitors of rules, appropriate behavior, and low-impact camping techniques is an important responsibility. Wilderness rangers are seen in an almost uniformly positive fashion by visitors; Stankey (1973) reported that 60 to 70 percent of the respondents favored the presence of rangers, and Lucas (1985) found a five to one margin in their favor in both years of his trend study. Hendee and others (1968) found that two-thirds of their sample disagreed with the idea that it is not necessary to patrol backcountry areas regularly. In West Virginia's Cranberry Backcountry, Echelberger and Moeller (1977) found that nearly two-thirds of the visitors felt regular ranger patrols would improve the quality of the experience. Virtually nowhere is there any evidence that wilderness rangers are an unwelcome intrusion on the visitor's experience.

Wilderness managing agencies have worked hard to inform and educate visitors in minimum-impact techniques. This approach is attractive for a variety of reasons. It takes managers out of the "policeman" role they can easily evolve into under a regulatory approach. Given the generally high level of educational attainment of wilderness visitors, a management strategy focused on the provision of information, coupled with a rationale, is likely a highly effective approach.

Lucas (1985) concluded that some of these agency efforts are paying off. In 1970, most visitors said burying unburnable trash was desirable, but in 1982, over two to one said it was undesirable. Also, in 1982 over 90 percent said that packing unburnable garbage out of the wilderness was desirable.

Thus, it appears that educational messages can result in changes in attitude. Linkage to behavior is, of course, another question. It also remains a question as to whether an educational approach to wilderness management can control effectively all the various problems that arise. To the extent that it cannot, other strategies employing regulation or even limitation might have to be instituted. What visitor attitudes exist toward these approaches?

Management of Recreation Behavior.—A wide number of techniques have been and could be implemented that focus on specific aspects of recreation behavior such as where people camp, how long they stay, or how many people are in a party.

Stankey (1973) asked respondents their opinion about two measures that would affect access into, and within, the wilderness. First, visitors were asked to respond to the idea of reducing the number of signs and trails within the area (in the BWCA, the idea was to "leave portages rough so that only those persons willing to make the effort could visit the area"). Overall opinion was split, with 41 percent favoring and a similar percentage opposing it. In the West, only about a fourth of those on horseback supported it, a reflection of concern with their ability to travel through an area. Overall support in the BWCA was a bit higher, with 47 percent in favor; surprisingly, there was no difference in support between paddling canoeists and those using outboard motors. Purists generally were more inclined to favor the action than other users.

Stankey also asked visitors about the idea of blocking off the access road at some point so that the hike to the wilderness would be longer, thereby likely filtering off some use. About 40 percent of the visitors in the three western areas rejected this approach, and in the BWCA 60 percent opposed it.

Roggenbuck and others (1982) asked visitors in the East their attitudes toward building more trails and the assignment of departure points as techniques for distributing use. The assignment of departure points received little support, with less than a fourth in each area favoring it. Between a third and a half favored building more trails.

There is an ambivalence on the part of many users toward various use distribution techniques. This ambivalence likely derives, on the one hand, from the feeling that such measures could help reduce crowding and perhaps resource impact, but on the other hand, they might simply stimulate more use or spread impacts. However, perceived trade-offs such as these are seldom controlled in research. Thus, ambivalence might also be a function of differing assessments of the benefits and costs of these strategies.

Another common management action involves limiting party size. The rationale behind such action is that large parties might have a disproportionate impact on both the experiences of other users as well as the environment. Today, party size limits, typically between 10 and 25 people, have been established for most wilderness areas (Washburne and Cole 1983).

Party size limits are well accepted by visitors. Tarbet and others (1977) found that a group limit of 12 was rated favorably by Salmon River visitors. A similar group limit was endorsed by nearly half the Chilkoot Trail hikers (Womble and others 1978). In three eastern wildernesses, between 70 and 80 percent of the visitors supported a limit on group size (Roggenbuck and others 1982). Roggenbuck and Schreyer (1977) found that 84 percent of river runners in Dinosaur National Monument favored some sort of maximum group size. Lucas (1985) found that opinion about party size limits remained stable over the 12-year period in the Bob Marshall Wilderness complex, with over half supporting a 12-person limit and only about 20 percent opposing it.

Stankey (1973) found a range of attitudes toward party size limits. In the BWCA, opinion was split, with half opposing such action and half either supportive or neutral. About two-thirds of the paddling canoeists supported limits, while two-thirds of the motor boaters opposed them. Among visitors to the Bridger Wilderness, 70 percent favored a limit on party size. In the Bob Marshall and High Uintas, 30 and 40 percent, respectively, favored restrictions on the size of horse parties. Both areas receive significant horse use. Although a party size limit of, say, 12 would affect primarily horse groups, an analysis controlling for method of travel provided only limited evidence that backpackers supported such limits as a way of controlling horse groups; 62 percent of backpackers supported a limit of 12, but so did 55 percent of the horsemen.

In a study comparing use and attitudes in a lightly used wilderness with those in a heavily used area, Stankey (1980) examined visitor views regarding party size restrictions. In the heavily used Desolation Wilderness in California, eight out of 10 agreed there should be a limit to the size of parties visiting a wilderness, while in the lightly used Spanish Peaks in Montana, only about half agreed. Among those in both areas who felt such a limit was needed, about three-fourths felt a limit of no more than 10 people was acceptable. In the Desolation, where there is little stock use, nearly 40 percent said there should be no stock allowed, while another 40 percent felt between one and four animals would be acceptable. As with many other attitudes, dispositions are shaped by local conditions and experiences. Where these are relatively stable across areas, useful generalizations can often be made, but where sharp local differences exist, it is more difficult to make such statements.

One type of direct regulation that has received much attention in the literature involves assignment of recreationists to campsites. The rationale is that such a program could help reduce crowding at sites and could also help protect certain fragile settings.

Visitor response to campsite assignment, however, is generally negative. Echelberger and Moeller (1977) found that 42 percent of the respondents in the Cranberry Backcountry said assigning campsites would reduce the quality of the experience and only one-third thought it would improve quality. On the Chilkoot Trail, 57 percent of the hikers disagreed with such an action; one-third did support it (Womble and others 1978). Stankey (1973) found very strong opposition to campsite assignments, with over 80 percent of the visitors opposed to them and only 6 percent supportive. In a 1980 investigation, Stankey found that assigning campsites was rated less favorably than charging a fee by visitors to the Spanish Peaks and the Desolation Wilderness; only 23 and 17 percent, respectively, approved of such a step. Roggenbuck and others (1982) found only about 20 percent of the visitors in three eastern wildernesses supported campsite assignment. Lucas (1985) reported a stable pattern of disapproval to campsite assignment (roughly three-fourths opposed) in his study of trends in wilderness use between 1970 and 1982.

An exception to this general trend is found among some whitewater river runners. In Dinosaur National Monument, river runners favored an assignment system four times more than they opposed it (Roggenbuck and Schreyer 1977). This appears associated with the limited availability of campsites along the river and the feeling on the part of users that such a system offers more certainty for finding a campsite at night. In terrestrial wilderness settings, it appears most visitors prefer searching for sites and expect, even in heavily used areas, that they can find one suitable to their tastes. Even being unable to locate a desirable site, however, appears preferable to being assigned where they have to camp, a step that seems to strike at the spontaneity and freedom that motivate much use.

Schreyer and Nielson (1978) found a mixed response to assigned campsites by river runners in Westwater Canyon on the Colorado River and Desolation/Gray Canyons on the Green River. Over 55 percent of the Westwater users favored such a system, with about a third opposed; however, on the Desolation, the percentages were exactly reversed.

These and many other regulations of wilderness visitor behavior have been implemented with varying success. Use conditions and associated impacts, however, can reach a point where such regulations cannot accomplish area management objectives. At this time, it might become necessary to implement controls on use numbers through some form of rationing. In the last part of this section, we examine visitor attitudes toward direct use restrictions.

Direct Use Limitations.—The idea of restricting entry to wilderness is, in many ways, an anathema. The very idea of wilderness suggests freedom and a lack of control; restricting that freedom through the imposition of limits seems to strike at the very heart of what wilderness is all about. The dilemma arises, of course, from the fact that the view of wilderness as an unrestricted commons can lead to use levels that jeopardize the important social and ecological values such areas contain.

Despite these concerns, many users express a general willingness to accept limitation. One exception was reported by Hendee and others (1968); almost five out of 10 persons did not feel that use of wilderness-type areas needed to be restricted and only 30 percent agreed it did. However, these data were obtained over 15 years ago, at a time when use in many areas had not reached the levels it since has. Lucas (1985) found that visitors in both 1970 and 1982 strongly supported the idea of "restricting the number of visitors to an area if it is being used beyond capacity" (no definition of capacity was given); over three-fourths answered that this was desirable and only 12 to 14 percent said it was undesirable. Tarbet and others (1977) found that the management option of restricting the number of users received a mean score of 2.9 on a scale of 3 (with 3 being desirable); this was the highest mean score recorded on any possible management action about which visitors to the Salmon River were asked.

Stankey (1980) asked visitors to the Spanish Peaks Primitive Area and Desolation Wilderness to respond to three statements concerning how they felt about management actions that should be taken if use were to continue to increase. First, it was suggested:

> It would be better to be able to go to the wilderness whenever you want to, even if it was being used beyond capacity, than to have any kind of regulations on use.

In response to this item, 83 percent of the Desolation visitors and 74 percent of the Spanish Peaks visitors expressed disagreement. It is clear from the response that unrestricted entry, when capacity has been exceeded, is not acceptable. Desolation visitors were more inclined to disagree with the statement than Spanish Peaks users, but this seems consistent with the much higher use there.

Users were then asked to comment on two additional items:

> There should be restrictions on how many people can be in a wilderness at any given time.
>
> and
>
> If a wilderness becomes overcrowded, restrictions on the number of people allowed to visit it should be enforced.

About half of the Spanish Peaks visitors agreed with the first statement; in the Desolation Wilderness, nearly nine out of 10 agreed. However, in the second item, which at first appears to merely restate the first, the differences in attitudes between the two were much less sharp, although still statistically significant; nine out of 10 of the Desolation visitors agreed with it, and three out of four of the Spanish Peaks visitors also agreed. The difference appears linked to the fact that the first statement proposes use restrictions without considering carrying capacity. In the Spanish Peaks, where use levels were low and most visitors felt the area's capacity had not been exceeded, only about half agreed with it, but nearly 90 percent of the Desolation Wilderness visitors agreed with the statement, an outcome that can probably be attributed to the high use levels currently found in the Desolation.

With regard to the second item, support for restricting use when the area became overcrowded grew sharply in the Spanish Peaks; by adding the crowding proviso, the item took on a condition with which most Spanish Peaks visitors could concur.

Interarea differences in use also yielded differences in attitudes toward control in three eastern wildernesses studied by Roggenbuck and others (1982). The major difference among areas was when the need to impose controls might arise. In the Shining Rock, which has one of the highest use densities in the country, nearly one-fourth thought controls were needed immediately to lower use, another 30 percent thought they were needed now to hold use at current levels, and nearly 40 percent thought they would be needed in the future. In the Joyce Kilmer/Slickrock, on the other hand, a lightly used area by eastern standards, the majority of users felt controls would be needed, but only in the future and when overuse occurred. In all areas, there was little support for the idea that controls were not needed at present or in the future.

Bultena and others (1981b) found strong opposition among Mount McKinley (Denali) National Park backpackers toward allowing uncontrolled use levels in the backcountry. Womble and others (1978) found divided opinion among Chilkoot Trail users; in response to the item "the number of hikers on the Trail at any given time should be limited," 37 percent agreed and 38 percent disagreed, while in response to "the number of hikers in camping areas at any given time should be limited," an identical 39 percent agreed and disagreed. A wide variety of reasons for these views were presented, ranging from support based on concerns for resource protection, to opposition based on concern for the protection of personal freedom, and even some based on the fact that historically there had been no limits to the Trail. Schreyer and Nielson (1978) found that only about 6 percent of whitewater river runners were in favor of removing all restrictions on the number of users on rivers; between 80 and 90 percent were opposed to such a move.

While there is generally strong support for the idea of restricting wilderness use, particularly when problems of crowding or resource impact are imminent, how should such restrictions be implemented and what public attitudes exist toward these different measures? Many specific techniques have been proposed to restrict use. Each carries a different type of cost and impacts different users. Consequently, we would expect different types of users to hold different opinions about these various alternatives, opinions shaped in part by how they see the action affecting them (Stankey and Baden 1977). Five broad strategies of use restriction can be identified. These include (1) queuing (first-come, first-served), (2) reservation, (3) pricing, (4) lottery, and (5) merit.

1. Controlling use through a queuing or first-come, first-served system is a common way of regulating entry to a scarce resource. In the wilderness situation, it tends to favor the local user or the person with abundant time (Stankey and Baden 1977). Stankey (1973) found that 28 percent of respondents favored a first-come, first-served system, with another 18 percent neutral; thus, nearly half were in favor or not opposed while slightly over half were not in favor. Consistent with the resident bias noted above, he found greater support in the Bob Marshall Wilderness, where most users were locals, than in the Bridger Wilderness, where nonresidents were predominant. Later, Stankey (1980) found that Desolation Wilderness visitors favored the first-come, first-served approach substantially more than did Spanish Peaks visitors

(57 to 41 percent). Both areas draw their use predominantly from local areas; over 90 percent of Desolation visitors come from California and over 70 percent of those in the Spanish Peaks come from Montana (Lucas 1980). However, the Desolation Wilderness is one of the most densely used areas in the country while the Spanish Peaks is one of the lightest (Stankey and others 1976). Consequently, Desolation visitors tended to be more supportive of all use control measures than did Spanish Peaks visitors. Moreover, a mandatory permit system in effect at the time of the study in all California wildernesses, distributed in part through a first-come, first-served system, likely resulted in more visitors there being familiar with it.

Roggenbuck and others (1982) also found fairly strong support for queuing. Support ranged from 41 to 52 percent. The Linville Gorge had such a program in effect at the time of the study, and 50 percent of the respondents indicated support for it.

Only slightly more than a fourth of the whitewater river runners surveyed by Schreyer and Nielson (1978) favored a first-come, first-served system. Commercial passengers in Westwater Canyon were more in favor of this system than were the private runners, but this ranking was reversed among the Desolation users.

Although a first-come, first-served system tends to favor local users, Bultena and others (1981a) found strong support for such a system among backpackers in the Mount McKinley backcountry—82 percent of the users supported this system. It should be noted that the permits for Mount McKinley backcountry use were distributed through a first-come, first-served system; thus, users were familiar with it.

2. Another common system involves reservations. A reservation system tends to favor those able and willing to plan ahead and whose time commitments are more predictable (Stankey and Baden 1977). However, when reservations can be obtained freely, there is a tendency for people to obtain them even if there is only a small chance they might eventually use them, often resulting in a large share of "no shows," resulting in a suboptimal allocation of the resource. Stankey (1973) found opinion fairly evenly split among wilderness users; overall, 43 percent supported a reservation system and 39 percent opposed it. Nearly one person in five was neutral. Among purists, the reservation system was rated as most favorable.

Stankey (1980) found a sharp split in opinion in his study of the Spanish Peaks Primitive Area and the Desolation Wilderness. Only 29 percent of the Spanish Peaks visitors favored a mail reservation system, but in the Desolation, 59 percent did so. The familiarity that Desolation visitors had with a mail reservation system then in effect in California probably accounted for much of the difference. This appears to be the case in a study reported by Roggenbuck and others (1982) where 85 percent of the Linville Gorge visitors supported an advance reservation system (and where such a program was already in place), while in the Shining Rock and Joyce Kilmer/Slickrock Wildernesses, two-thirds of respondents supported such a system. In a study of river runners on the Middle Fork of the Salmon River in Idaho, Utter and others (1981) found strong support for reservation systems, likely reflecting the fact that such users typically are more familiar with such systems than most backpackers.

Schreyer and Nielson (1978) reported strong support for a reservation program among whitewater river runners; about 80 percent of those surveyed in the Westwater and Desolation Canyons favored such a program. Commercial passengers were more strongly in favor of the advance reservation program than were private runners.

Nearly half (46 percent) of Mount McKinley backpackers opposed an advance reservation system (Bultena and others 1981a) while 37 percent supported it and 14 percent were neutral.

3. One of the most common techniques in society for the allocation of scarce resources is pricing. However, when considered as a mechanism for the allocation of recreation and amenity resources in general, or wilderness in particular, pricing is often seen as unacceptable or inappropriate.

Nevertheless, several studies have looked at the use of pricing as a way of limiting use. One study (Hendee and others 1968) asked if visitors would be willing to pay some charge to help defray the costs of backcountry administration and management. More than four out of 10 persons were willing to do so, one-third were opposed; those persons who were classed as more purist in attitude were particularly opposed to such a charge.

The notion of a fee has received some support. Even at the time of the ORRRC Study (1962), charging for wilderness entry received support. That study asked, "If it were necessary to charge a yearly license fee in order to preserve wilderness, what would be the maximum price you would be willing to pay?" Slightly over a fourth replied "nothing" but another fourth replied between $3 and $5.

Stankey (1973) also found about a fourth of respondents favored a fee while 20 percent were neutral. Among purists, there was mixed opinion; overall, about 45 percent opposed a fee, but the percentage favoring one ranged from 23 to 53 percent among the different areas. This pattern persisted in Stankey's 1980 report on the Spanish Peaks Primitive Area and Desolation Wilderness. About one-fourth of Spanish Peaks visitors and one-third of Desolation visitors supported a fee. It also prevailed in a study of users in three eastern wildernesses (Roggenbuck and others 1982) where about one user in five supported it. Two-thirds of the respondents in the Mount McKinley backcountry opposed a fee and only one in 10 supported it (Bultena and others 1981a). Still, nearly 20 percent were neutral to the idea of charging.

4. The concept of a lottery as a means of allocating wilderness use opportunities has been proposed as a system that would eliminate many of the advantages and disadvantages of other distributive systems (Hardin 1969). In this system, much as in the programs that many States have implemented to allocate certain hunting permits, one's chance to visit an area would ride on the "luck of the draw."

It appears that many people are not willing to leave their wilderness visits to chance. In the four studies reviewed where attitudes toward a lottery were examined (Stankey 1973, 1980; Bultena and others 1981a; Roggenbuck and others 1982), it was the least favored of all rationing programs, ranking even below the imposition of a fee. Overall, support ranged from a low of about 6 percent to a high of around 18 percent. These results persist over a wide geographic area and over a period of 10 years, altogether a remarkable measure of stability.

A lottery also rated poorly among whitewater river runners. Overall, only about 20 percent of those surveyed by Schreyer and Nielson (1978) favored a lottery, and although private river runners were more supportive than the commercial passengers, a majority of both groups opposed a lottery. One exception to this general pattern is in Utter and others' (1981) study of river runners where they found support for the use of lotteries.

5. Rationing by merit received much attention in an article by Hardin (1969) and, even today, has many advocates. Many of the ideas underlying the concept of minimum-impact camping originate from the merit idea. The basic concept is that by requiring individuals to have some minimum level of skill and knowledge about use of the backcountry, many undesirable impacts can be eliminated, thereby reducing the need for restrictions.

Only limited data exist regarding visitor attitudes toward such an approach. Stankey (1980) asked visitors to the Desolation Wilderness the degree to which they favored or opposed being required to take a test of their wilderness skills and knowledge. Nearly six out of 10 supported such a policy. Utter and others (1981) found that a majority of users on the Middle Fork of the Salmon River supported a merit option, although the item as presented in the questionnaire might have led people to believe that it referred to their guide's experience and not their own. Bultena and others (1981a) reported substantial opposition to such an approach, with half of the Mount McKinley backpackers surveyed opposed and only about a fourth in favor.

Shelby and others (1982) examined the attitudes of river runners and backpackers toward the five general use rationing programs we have reviewed in terms of four criteria: their effect on the chance of obtaining a permit, their fairness, their acceptability to users, and the willingness of users to try them. The results (table 2) indicate that pricing and reservation systems rank highest with regard to all the criteria for both river runners and backpackers, with one exception: a merit system is seen by backpackers as having less effect on them than a reservation system.

Most studies reviewed here have tapped the attitudes of visitors toward the various rationing schemes in a hypothetical or abstract sense. However, two studies have reported attitudes toward a specific program. Fazio and Gilbert (1974) surveyed backcountry users in Rocky Mountain National Park to determine their reaction to a program instituted to control overnight use. People were surveyed both before and after they visited the area. Although people were required to wait for up to 1½ hours to obtain a permit, 69 percent of those queried in the pretest and 86 percent of those in the followup survey viewed the system as necessary. Even among those unable to obtain a permit, 80 percent still saw the permit system as necessary.

Table 2.—Percentages of users agreeing with four assessments of allocation alternatives (source: Shelby and others 1982, p. 418)

Allocation alternative	River runners Hells Canyon (N = 295)	Backpackers Eagle Cap (N = 118)	Backpackers Mt. Jefferson (N = 261)	Chi square[1] (d.f. = 2)
	Percent	*Percent*	*Percent*	
Little or No Effect on Chances of Obtaining Permits				
Pricing	48	70	54	[2]13.12
Reservation	64	56	45	[2]35.07
Lottery	31	20	19	[2]11.41
Queuing	14	41	38	[2]47.27
Merit	37	66	66	[2]46.69
System Is Fair				
Pricing	45	49	43	1.51
Reservation	78	50	48	[2]53.14
Lottery	39	19	21	[2]26.16
Queuing	12	34	29	[2]36.08
Merit	23	24	34	7.45
System Is Acceptable				
Pricing	66	66	55	5.85
Reservation	95	73	74	[2]46.19
Lottery	50	28	30	[2]23.97
Queuing	25	50	51	[2]40.40
Merit	37	42	49	5.91
Willing to Try System				
Pricing	62	68	64	1.16
Reservation	84	71	64	[2]32.32
Lottery	51	35	37	[2]11.88
Queuing	16	53	55	[2]96.35
Merit	36	56	60	[2]32.97

[1] Chi squares are based on 3 × 2 tables comparing responses across the three user groups.
[2] $p<0.005$.

Similar results were obtained by Stankey (1979b) in a study of use rationing in two southern California wildernesses. He found that among successful applicants, 82 percent supported implementation of the rationing system and only 5 percent opposed it. And as Fazio and Gilbert had reported, even unsuccessful applicants supported the system; 81 percent were in favor of it and only 5 percent were opposed.

The conclusions of Shelby and others (1982) mirror those that we derive from this review of visitor attitudes toward the various rationing schemes. Users generally support the idea that management policies need to be implemented to protect the quality of wilderness and backcountry experiences. There is a recognition that unlimited use is not consistent with the kinds of conditions and experiences such areas are to provide. However, when we consider specific techniques, the characteristics of different areas, activities, and clients affect judgments of their appropriateness. Because each system imposes different impacts on users, it is necessary to consider the specific characteristics of an area and its use to determine the most appropriate approach.

Bultena and others (1981a) offered important evidence as to how the orientation of visitors affects their appraisal of different management policies. Overall, their data showed that the backcountry policies at Denali National Park, although restrictive, were endorsed by most visitors. Within this broad pattern of support, however, there were sharp differences of opinion, revolving largely on the underlying orientation of the respondent toward wilderness. The investigators considered how the appraisal of different management policies varied according to the importance respondents placed on solitude and their preference for resource development (the extent to which they favored the provision of more facilities in the backcountry). As table 3 shows, those backpackers seeking solitude were also those most supportive of the need for rationing and of the existing management policies in the park. Conversely, those most development-oriented were the least supportive of rationing and the park's restrictive use control measures. However, there were generally no differences based on the alternative orientations toward specific rationing steps.

Summary of Attitudes About Management

In reviewing the results of the many studies discussed in this section, several general conclusions can be made. First, although the studies have been conducted over an extended time, over a wide geographic region, and have involved differing methods, sampling approaches, and questions, it is still possible to obtain some clear patterns regarding visitor attitudes toward management. Everyone does not have their own unique conception about how to manage wilderness. In fact, one of the major benefits of a review such as this is to help "tease out" some of these patterns and clusters of beliefs and to help managers better understand how these patterns relate to the actions they undertake and the decisions they must make. While some patterns do emerge, it is important to note that there is considerable variation in the attitudes of wilderness visitors toward management. Yet, many of these variations are related systematically to other factors, such as method of travel.

Second, although we can discern certain patterns in our review, it is difficult to ascertain trends in these patterns. With few exceptions, the body of research on visitor attitudes toward management is derived from cross-sectional studies, with limited comparability from one study to another. No longitudinal studies have been conducted; consequently it is difficult to assess what changes, if any, have occurred over time. Our review leads us to conclude that some marked changes have likely occurred and the trend study by Lucas (1985) supports this. There appears to be a move toward more appreciative, less consumptive styles of use, declining support for developmental responses to problems, increasing support for educative and information-based management responses, and a base of support for use restriction when conditions warrant it.

Table 3.—Relationships of hikers' solitude and development orientations to their attitudes toward rationing and existing management policies (source: Bultena and others 1981a, p. 307)

	Orientation		
Policy domain	**Solitude**	**Gamma**[1]	**Development**
Desirability of rationing	+0.30		−0.38
Alternative rationing systems			
First-come, first-served	+.19		−.19
Lottery	0		+.04
Registration	−.10		+.12
Merit	+.03		+.02
Entrance or use fee	−.10		+.06
Existing management policies (management policy score)	+.17		−.29

[1] The contingency tables from which the gammas were obtained had five response categories for the "desirability of rationing" and each of the five "alternative rationing systems." The management policy score, solitude orientation, and resource development orientation were each broken into three categories. Tests were not made of the statistical significance of relationships because the full universe, rather than a sample, was surveyed.

Such conclusions rest on a limited data base. The extent to which the findings reviewed here or reported by Lucas can be generalized is not clear; it is our assessment that today's wilderness user supports a more purist perspective about wilderness management than his or her counterpart a decade ago.

A third conclusion we can make is that many studies reveal a tendency for users to support the status quo. Some of this might derive from the legitimate belief that what exists now is fine and any changes will only detract. The belief might also derive from concerns that changes will alter the character of the setting in ways that will attract more users or a different kind of user. The principal implication for managers is that cross-sectional attitude surveys provide only a measure of opinion at one time. Without a context within which to place such data, results are difficult to interpret. Being able to compare the results of one study with those obtained at a different place or time provides a basis for appraising how such results might be interpreted and used.

The expressed preference for the status quo also holds important implications for the manager contemplating change. As we stated earlier, attitudes are not a prescription for management; conditions might dictate that despite a seeming contentedness among present users, new actions must be implemented. In such cases, however, managers need to match implementation of any new action with efforts to inform users of the need and rationale for that action. Attitudes do change in response to information, and managers can play a critical role in this process.

Fourth, on virtually all issues, a diversity of opinion exists. Typically we focus on whether more people support or oppose some issue. However, we believe it is important to review the full spectrum of opinion: the level of support, the level of opposition, and the extent to which a neutral opinion exists. To be neutral is to have an opinion. It might reflect a legitimate view that it really doesn't matter, or it could reflect an equally legitimate view that people simply cannot arrive at an opinion, either because they have not had adequate time to think about it or because they lack adequate information to make a judgment. The neutral category represents an important group in situations where opinion is evenly divided between pro and con; in these situations it might represent a potential "swing vote" in public sentiment. Accurate information about the reason for some action or the implications of some step can be critical in influencing how people might move from a neutral stance.

It is also important to examine the distribution of opinion at the extremes. Strongly held views, either for or against, can be suggestive of likely behavior. When opinion is not just against, but is strongly against some issue, managers have an important indication that the issue is particularly sensitive. Proceeding with the proposed action demands care and planning lest public opposition overwhelm it.

Finally, we have seen how opinion about various management actions differs among user groups according to a variety of factors—their method of travel, relative level of wilderness experience, and intensity of attitudes toward wilderness. All these factors permit a more critical as well as useful analysis of the data. Users differ in many ways, leading them to appraise management actions in different ways. By grouping users into categories, we are able to segment the user population into subunits possessing more uniform conceptions of wilderness and its use and management. This provides a more useful method of looking at the distribution of opinion about an issue. If there is opposition to the provision of stock facilities, does it all derive from backpackers? If so, and the area provides a significant opportunity for horse use, the management response might be to separate user types. On the other hand, if there is opposition among horse users as well, then perhaps there is serious question as to the need for such facilities at all. Or, efforts to improve the stock handling capabilities of horse users need to be emphasized. In any case, a more refined analysis of the user population helps improve the ability to analyze and evaluate attitude data.

Visitor attitudes are particularly important to management in situations where there is conflict among users or feelings of dissatisfaction about existing conditions. As wilderness visitation has grown, so have perceptions of conflict and concerns for the impacts of this increased use. The following section explores these concerns and the reasons for them.

CONFLICT AND CROWDING IN WILDERNESS SETTINGS

As the last section has shown, the maintenance of wilderness requires active and diverse management. The fact that people value wilderness and desire to experience it produces a fundamental paradox: that appreciation may threaten the natural qualities that define wilderness environments. It has also raised an even deeper concern over the extent to which use should be regulated. Users are growing in numbers, coming in contact with one another, and experiencing conflict and crowding. If solitude is a fundamental aspect of the wilderness experience, the presence of others invariably impacts that experience.

The Concept of Carrying Capacity

Many have talked of the need to establish a carrying capacity in wilderness environments. The fundamental concept appears intuitively sound. It has been possible to identify carrying capacities for cattle and deer in wildland situations based on their impact on forage. Thus, it should be possible to recognize when recreational impacts are too great and use needs to be curtailed. Although such logic at first glance appears sound, the attempt to actually determine a carrying capacity is fraught with difficulty. There are many differences between complex humans moving through a wilderness and bovines browsing, though many cynics would not necessarily agree.

In this section we will discuss problems relating to visitor perceptions of conflict and crowding. Discussions of carrying capacity generally include concerns for impacts to the environment as well as the crowding dimension. The environmental impact dimension has been covered in depth in other papers in this collection. Here we focus on visitor reaction to impacts as well as to other recreationists.

There has been a substantial amount of research on the impacts of recreational use and visitor perceptions of crowding. Perhaps the most comprehensive effort to summarize this literature was undertaken by Graefe and others (1984). A related bibliography by Vaske and others (1984) is also available.

There has been much controversy over the establishment of a carrying capacity, and many have argued that the concept is not even a valid notion to apply to recreation (Schreyer 1979; Burch 1981). One of the more universally agreed on facts is that there is no such thing as *a* carrying capacity for an area. Rather, there are many possible capacities, depending on resource goals, visitor distribution and behavior, and environmental characteristics. Thus, rather than talk of *a* carrying capacity, it is more appropriate to consider the broader picture of managing for and regulating recreational use. This might require use limitation, but there can be many other ways of dealing with impacts or conflicts.

Graefe and others (1984) presented a model of the dynamics of visitor response to others in terms of two conceptual lines of inquiry. The first was expectancy theory, which assumes that people develop expectations for what they will encounter and then gauge what is actually encountered against those expectations. This is one of the fundamental underpinnings of the motive approaches to understanding visitor behavior described earlier.

Expectations can be general and diffuse, such as the expectation to experience nature. They can also be quite specific. For instance, a person might expect to camp at a specific campsite on a given lake with no other persons there. A person might desire to participate in wilderness recreation to experience solitude. The choice of a particular environment is based on the expectation that few people will be seen. If more people are seen, this can lead to dissatisfaction. Depending on the level of specificity, an expectation might be more or less strongly tied to feelings of dissatisfaction when encounters with others are greater than desired.

Their second line of inquiry was that of norms. Norms are standards for evaluation of behaviors, persons, or situations (Cancian 1975). As norms are invariably socially influenced ways of looking at the world, we view shared norms as "social norms" (Black and Heberlein 1976). People can share norms concerning what the appropriate level of use for an area should be, as well as what should be appropriate behaviors of users and levels of impact to the environment. To the extent these norms are reasonably well-defined among group members, they should be measurable and standards for levels could be established.

Crowding can occur when numbers of others exceed one's expectations. These expectations can be shared in a social context and formalized as norms. Different dynamics can be used to explain these workings. "Discrepancy" models suggest dissatisfaction is a function of the gap between what was expected and what was encountered (Peterson 1974b; Becker 1978; Schreyer and Roggenbuck 1978). "Social interference" models imply that negative outcomes arise when the presence or behavior of others interferes with the individual's attainment of desired goals (Jacob and Schreyer 1980). "Stimulus overload" models are founded on the notion that problems arise when encounters with others result in greater social interaction than desired (Baumgartner and Gundry 1978; Gramann 1982). All these models agree that it is necessary to understand the experiences and outcomes sought by recreationists to understand their reaction to encounters with others (Graefe and others 1984).

The Assessment of Crowding

There is tremendous complexity in the human response to the natural environment. Given this complexity, there is a temptation to avoid comprehensive examination of these issues by concluding "everyone is different" and managing for the mythical average visitor or the lowest common denominator of human perception. However, simplifying such complexity does not resolve problems resulting from too many visitors to the wilderness; rather, it demands a more sophisticated understanding of the forces at work in assessing perceptions of crowding.

Human response to others is affected by a variety of background and situational variables. We can easily assess the objective dimensions of human interaction. Increasing use levels in wilderness can be shown to relate to an increasing level of encounters among visitors (Shelby 1976, 1980b; Heberlein and Vaske 1977; McDonald and Hammitt 1979). Increased encounters are generally associated with increased perceptions of crowding (Schreyer and others 1976; Bultena and others 1981b; Womble and Studebaker 1981; Hammitt and others 1982; Graefe and others 1984). However, density is not equivalent to crowding. Density refers to the number of individuals in a given setting, while crowding relates to the negative evaluation of that density. That evaluation is affected by many factors (Altman 1975).

Problems from the presence of others might not result from direct encounters. People can respond more strongly to impacts perceived as being caused by others than actually seeing them (Lee 1975). In many cases, visitors are likely unaware of impacts (Cole and Benedict 1983). Even if the impact is noted, it might not have an adverse effect on the visitor's experience if judged not to be important (Lucas 1979; Graefe and others 1984). Further, visitors might be more sensitive to evidence of humans, such as litter, than to actual impacts to the environment, such as eroded trails (Frissell and Duncan 1965; Stankey 1973). Impacts cannot only result in negative reactions, but can increase perceptions of the use levels of an area (Ditton and others 1983). Vaske and others (1982) found that "environmental disturbance" was the strongest predictor of perceived crowding in a wilderness.

Crowding, Satisfaction, and the Recreation Experience

A fundamental notion involved in these concerns is the belief that the perception of crowding negatively impacts the wilderness experience. This has usually been studied through an assessment of recreationists' satisfaction with the numbers of others encountered. Because the concept of recreation resource management is founded on the notion of providing opportunities for visitors to attain satisfaction, this appeared to be the most direct method of analyzing crowding.

Unfortunately, the situation has not been as straightforward as originally assumed. In many cases, use levels have not been related directly to satisfaction. Graefe and others (1984) summarized 36 studies measuring different dimensions of encounters and satisfaction. Of those studies measuring the correlation between actual density of an area and visitor satisfaction, only two showed a significant statistical effect, and both of those were positively correlated (Heberlein and Laybourne 1978; Heberlein and others 1982). Both involved studies of hunters in which the presence of others was seen as advantageous in driving the deer toward them.

In studies measuring the relationship between reported contacts and satisfaction, three were significant, but again two were in the positive direction (Hammitt and others 1984; Vaske and others 1983). Graefe and others (1984) did find a more consistent relationship between both actual density and reported contacts and perceptions of crowding. Further, there were consistent relationships between perceived crowding and level of satisfaction (Shelby 1976; Heberlein and Vaske 1977; Shelby and Colvin 1979; Ditton and others 1982; Vaske and others 1982, 1983).

Many of the studies reviewed by Graefe and others (1984) did not involve use in wilderness settings. Both conventional wisdom that assumes wilderness as a setting where there is little if any contact with others and research supporting visitor preference for low levels of interparty contact lead one to hypothesize that crowding in wilderness could be a problem.

Research by Stankey (1973, 1980) indicated a strong preference among wilderness visitors for low levels of interparty contact. Although responses to questions about the impact of rising use levels on satisfaction were based on hypothetical situations rather than actual use conditions encountered, the results pointed to the likelihood that visitor satisfaction declined as contact levels rose.

Lucas (1980, 1985) found evidence supporting this hypothesized relationship. The relationship between visitor satisfaction and level of use encountered, measured three different ways, was negative, although the strength of this relationship declined over the decade between the two studies.

Desired Outcomes.—The numbers of others encountered is not the sole consideration in determining satisfaction in a recreation experience. Schreyer and Roggenbuck (1978) showed that perceptions of crowding are linked to the strength of crowding-sensitive outcomes, such as stress release and solitude. However, if such outcomes are not important, the presence of others need not be disturbing (Stankey and McCool 1984). Recreational engagements are entered precisely because we want them to be satisfying. Thus, even if we would have preferred to see fewer people, we might be unwilling to let certain negative aspects such as this impact that satisfaction (Heberlein and Shelby 1977).

Schreyer (1979) suggested that people might use any number of coping mechanisms, such as emphasizing more crowding-independent outcomes and altering perceptions of the numbers of people actually present to avoid negative outcomes (Schmidt and Keating 1979; Gramann 1982). Further, people might have few strictly defined expectations about numbers of others they might encounter (Cheek and Burch 1976).

Behavior Change.—People can change their behavior patterns in response to crowding. Thus, although numbers might be high, those most sensitive to such conditions avoid situations of high density. Such behavior shifts are referred to as displacement. The extent to which displacement occurs is arguable. In a study of river floaters in the Grand Canyon, Nielsen and Endo (1977) found that, although some boaters moved to lower density rivers, others moved to higher density ones. Anderson (1980) documented displacement among visitors to the Boundary Waters Canoe Area. Although displacement was noted, she found no differences among persons based on amount of experience. Other studies have shown some displacement among visitors from more crowded to less crowded environments for a variety of water-based activities (Heberlein and Vaske 1977; Nielsen and Shelby 1977; Vaske and others 1980; Becker 1981a).

Conflict vs. Crowding.—People might respond not merely to numbers, but rather to the behavior of others (Stankey 1972). Conflict can make people more sensitive to the numbers of others, and thus make an area seem more crowded. Jacob and Schreyer (1980) define conflict as "goal interference attributed to another." They suggest that conflict occurs when others frustrate a person's desired outcomes for an experience, or when they violate norms of appropriate behavior as defined by those persons. Such norms could relate to the activity, or they could be defined as appropriate behaviors for the recreation place. Some conflicts are fueled by the perception that others possess a different lifestyle with ways of behaving and values threatening to those experiencing conflict. This is a strong force leading to conflict among different "types" of recreationists, such as hikers and horseback riders.

User Types.—Graefe and others (1984) pointed out that different types of users differ in their sensitivity to others. This again is likely due to their seeking different outcomes and having different norms about appropriate encounter levels. It is difficult to generalize perceived crowding of visitors to an area because they might differ widely in perceptions of the same encounter levels. Because different types of users perceive crowding in different ways, making decisions about crowding inherently implies a judgment favoring one type of user over another (Schreyer 1976).

Confrontation and conflict often underlie crowding perceptions. Graefe and others (1984) presented a tabular representation of a number of studies comparing crowding perceptions of different types of visitors. They dichotomized the types as "sensitive" or "tolerant" to the presence or behavior of others. Among these sensitive/tolerant types are several found in wilderness: nonmotorized/motorized water-based recreationists (Adelman and others 1982), fishermen/other water-based recreationists (Driver and Bassett 1975; Gramann and Burdge 1981; West 1982b), frequent/infrequent participants (Graefe 1981), experienced/inexperienced visitors (Nielsen and others 1977; Schreyer and Nielson 1978; Vaske and others 1980; Ditton and others 1982; Hammitt and others 1984), high status/

low status participants (West 1982a), and solitude seekers/thrill seekers (Absher and Lee 1981).

Group Dynamics.—Many differences noted above enhance the notion that crowding and conflict perceptions are asymmetrical; that is, one group can experience conflict while another does not. Other elements of group dynamics can affect crowding perceptions. For instance, people might be particularly sensitive to encountering large groups (Lime 1972). They might prefer to see many smaller groups in a wilderness setting than one very large group, even though they might see the same number of people (Stankey 1973; Pfister and Frenkel 1974).

Individuals highly committed to an activity can have a more strongly defined sense of appropriate behavior. This is reinforced in group settings to intensify perceptions of conflict with others' behavior (Driver and Bassett 1975; Gramann and Burdge 1981; West 1982b). Individuals can reinforce their own sense of commitment and belonging to a given social group by acting out perceptions of conflict of others. Thus, the group might not only define norms of behavior, but might channel the perceptions of participants toward the conflict, thereby catalyzing more negative feelings than would otherwise be there. The extreme expression of this dynamic is "mob effect."

Situational Factors.—Graefe and others (1984) noted that many factors influencing perceptions of crowding depend on where those perceptions occur and under what circumstances. For instance, people tend to be less sensitive to seeing others at the border of a wilderness than in the interior. In particular, the sensitivity to crowding appears to be heightened at the campsite. Stankey's studies report strong visitor preference for campsites screened from the sights and sounds of others (Burch and Wenger 1967; Stankey 1973). Lucas (1985) found a fairly strong association between visitor satisfaction and success in finding desired campsite solitude; eight out of 10 respondents preferred no other persons camped within sight or sound and about two-thirds reported they were able to find such conditions consistently. Heberlein and Dunwiddie (1979), in observing wilderness campsite selection in a portion of Wyoming's Bridger Wilderness, reported that experienced visitors were more likely to select sites farther from others and to select sites in zones containing the fewest other occupied sites. Further, the length of time that others are encountered might affect the sense of crowding (Titre and Mills 1982).

Designation of the area can have an effect. Shelby (1981a) suggested that persons in designated wilderness tend to be more sensitive to crowding than persons using undesignated but undeveloped recreation areas. This is likely due to the acceptance of definitions of the norms attributed to a certain recreation place (Lee 1972). It could also be a function of the tendency to assume that a designated area is of "higher quality," leading to higher expectations (Anderson 1980).

The person's relationship with the environment can also be a factor. If the individual has seen the environment change over time, with increasing numbers and diversity of use, this can result in a greater sensitivity to the presence of others (Driver and Bassett 1975; Vaske 1978). This is particularly the case if the person values the place highly and has a strong attachment to it (Jacob and Schreyer 1980).

In summary, numerous studies have focused on conflict and crowding in wilderness settings. Given the legislative mandate defining solitude as a key attribute of wilderness, this is not surprising. The research reveals considerable visitor concern with problems related to crowding and associated impacts.

Some reasonably well-agreed-on conceptions of appropriate interparty contact levels in wilderness settings are found in the literature. Most visitors prefer that daily contact levels not exceed two or three other parties. There appears to be even more consensus about appropriate use levels at campsites; there is a decided preference for no others camped within sight or sound. The argument has been made, in fact, that the ability of a wilderness to provide campsites that offer visitors this level of isolation might represent a "bottleneck" on the area's overall capacity (Stankey 1973).

The asymmetry in felt conflict between groups is also a consistent finding. The most obvious manifestation of this conflict is between groups using different methods of travel, such as hikers and horseback riders or canoeists and motorboaters. Persons traveling on foot or by paddling are highly sensitive to, and distressed by, contacts with persons traveling by other means, while this latter group shows less concern about the former. There appear to be some strong norms of appropriate behavior involved in this situation, ascribed to by the one group but not the other. The conflicts generated by these norms appear to be more critical than those brought about by encountering higher-than-preferred use levels.

The relationship between visitor satisfaction and encounter levels is complex. Following earlier work by Stankey (1973) that hypothesized declining satisfaction levels with rising levels of contact, empirical investigations of this relationship reported either no effect or, in many cases, an effect opposite to that hypothesized; that is, as use rose, so did satisfaction. Many of these studies, however, were conducted in nonwilderness settings where motives and expectations were not focused on outcomes related to solitude. Even in some wild river settings, characteristics of users (such as a large proportion of first-time visitors with ill-defined expectations about use) or situational characteristics (the excitement and thrill of running rapids, the noise of thundering water) likely diminish the significance of interparty contacts, further contributing to the conclusion that use levels have little effect on visitor satisfaction levels.

Increasingly, however, analyses have grown more sophisticated. Part of the explanation lies in recognizing the importance of different outcomes to visitors; for those to whom solitude is unimportant, rising contact probably has little significance. Conversely, for those who value solitude greatly, the presence of others can be a critical source of dissatisfaction. Moreover, we have come to understand that recreationists are able to employ a wide range of strategies to cope with situations they encounter so that they can continue to define their trip and experience in positive terms. Our understanding of the complexity of the concept of satisfaction continues to grow; the lack of a statistical association between use level and satisfaction might reflect more the crude state of our ability to measure satisfaction than anything else.

Measures of the preferred types and levels of interparty encounters are useful information for managers concerned with establishing estimates of appropriate use. They reflect the kind of conditions visitors seek and, as such, provide managers with a basis for establishing objectives related to visitor experiences. The difficulty in measuring visitor satisfaction associated with different use levels should not be taken as an indication that the level and type of use visitors meet while in wilderness is not a matter of great concern to many of them.

SOME CONCLUDING REMARKS

As we review the studies covered in this paper, three broad conclusions can be made. First, there has been an evolution from a situational descriptive approach to the study of attitudes and behavior to one founded much more rigorously in theory. Many early investigations, although tied to general notions of perception or other organizing framework, lacked clear, explicit theoretical underpinnings (Stankey 1982). More recently, the theoretical rigor of investigations has increased significantly.

Second, over the period covered by this review, more sophisticated analytical procedures have been employed, moving from straightforward descriptive accounts, including frequency distributions and cross tabulations, to multivariate analyses, including a variety of cluster analytic techniques. As a result, the power and complexity of analyses have increased.

Finally, we see an increasing interest in examining attitudes and behavior within a social, as opposed to a psychological, context. Recreation behavior is a social behavior; it takes place typically within a group structure, and groups play a special role in motivating, sustaining, and giving meaning to such behavior. However, group influence on recreation behavior has only recently received the attention it warrants. It is our judgment that such a focus will provide added strength and meaning to efforts to understand recreation behavior.

Information about wilderness recreationists' attitudes and behavior is increasingly viewed as important to the planning and management process. There is growing recognition that experiences produced in wilderness settings are of parallel importance to the preservation of the ecological processes that characterize and shape such areas. If any single conclusion can be drawn from the substantial body of literature that we have reviewed, it is that people, users and nonusers alike, place a very high value on wilderness and are concerned with its future. Although many lack a technical understanding of wilderness management and might not possess a clear understanding of the subtleties, implications, and consequences of the various actions they may undertake, no one should underestimate the interest and concern they hold.

As we have suggested in several places, a major implication for managers is the need to provide this highly motivated clientele with accurate information from which they can make informed input. In many instances, it is clear that people do not possess the level of information they desire or need to make such input, but it is just as clear that they desire a role in the decision process and that the views they hold about management are of increasing importance in making those decisions.

Here is where research has an important role and obligation. If policy decisions about the management of wilderness are going to be made with public input as one critical element, those making such decisions have to be assured that the base of information about that public input is sound and reliable. Managers have as much reason to be concerned with the concepts of validity and reliability as scientists. There is often a point of conflict between the researcher and the manager on this matter. The manager sees the research worker's concern with the trappings of science—sample design, tests of significance, and so on—as clutter that holds up the delivery of the answer. The researcher, on the other hand, views the demands of the managers as another contaminant to be dealt with in the conduct of good science. The end result is often dissatisfaction on the part of both parties.

But as Shelby (1981b) has noted, both parties have important obligations in the process of integrating research findings into the management process. Chief among these obligations are the need to maintain an interactive environment where concerns can be expressed, to carefully define how research findings can and will be used, and to recognize that the development of a good information base from which sound decisions can be made requires time, money, and effort. We might also add that research findings, by themselves, seldom provide straightforward answers to the questions that face managers (Stankey 1979a). Such findings do, however, provide information that bears on these questions. It is in the interaction and dialogue that must accompany such applied research that both the limitations and opportunities inherent in the data can be drawn out.

As we look to the future and the needs for further research on attitudes and behavior, several issues seem apparent, some methodological, some substantive. Certainly one major area requiring attention is the need for longitudinal research designs that provide a sound basis for trend analysis. Such analyses could help identify major changes in client groups, tastes, and preferences that would serve as critical input into the revisions of management planning documents as well as provide important insight into how the image and meaning of wilderness are changing over time.

It is important that more work look at the role and meaning of wilderness in contemporary society, a perspective that extends beyond that held by the user. Users are only temporary tenants in the wilderness; however, such areas remain the property of society forever. The historical analysis pointed to the tremendous shift in societal attitude toward wilderness that has occurred in the past century; our review of attitudes toward management suggested some large changes have occurred in just the past 20 years. There seems little reason to presume this cultural evolution will not continue. We need to consider ways to monitor systematically such society-wide changes in perception.

We see a need for continuing work directed toward development of better ways to promote sensitive management systems in wilderness, techniques that ensure protection of the wilderness experience at the same time they ensure adequate protection of fragile wilderness ecosystems. Influences on behavior that correct depreciative acts in subtle yet effective ways need to be ascertained. We are particularly concerned with how information can better serve the needs of both manager and user.

It is clear that relatively well-defined rules of appropriate conduct do emerge—norms that provide a framework of appropriate behavior. How do these norms develop; how are they communicated, internalized, and reinforced; and what forces lead them to change? To what extent can managers utilize such internalized forms of behavior control to achieve area objectives? In particular, are there ways in which such norms can be utilized as the basis of standards designed to ensure maintenance of wilderness quality?

We see a need to obtain a better grasp of how wilderness recreationists make decisions and what factors influence those decisions. What role, for example, does information about social and site attributes play in the decision process? What are the key attributes of wilderness settings that influence visitor selection of sites and their subsequent satisfaction? What group influences operate to shape individual decisions? How are the images that people hold of wilderness formed, how do those images affect their decisions about the use of such areas, and to what extent can those images be altered in a manner compatible with wilderness preservation while respecting the individual's freedom of choice?

Studies of wilderness visitors reveal their great adaptability to changing conditions and their capacity to achieve satisfactory experiences in response to these changes. Yet, just as clearly, visitors hold well-defined preferences for certain conditions, such as levels of encounters with others. There is a need to better understand this adaptive process and to clarify the relationship between preferred states and those considered tolerable. This range of acceptability could serve a particularly useful purpose in prescribing management guidelines.

Science often seems concerned with being innovative, but there are strong reasons to encourage replicative research projects involving repetitions both in time and over space. The trend study by Lucas (1985) provides a unique opportunity to look at the changes occurring in one area over the span of a decade; such studies done elsewhere would be similarly beneficial. Many of the studies of attitudes and behavior, like many ecological studies, have been conducted in the Western United States. There is a need to replicate these studies elsewhere to determine the extent to which the patterns involved are universal and shared or unique and idiosyncratic. There is particularly a need for improved consistency in such replicative research and to search for patterns of generalization, especially in motive clustering and site attribute preference research.

The continuing issue of how well attitudes predict behavior remains with us. Many of the behaviors with which we are concerned and the behavioral influences involved are difficult to measure. Surveys of attitudes and other dispositions such as preferences and expectations are relatively more easily conducted. But if such measures have weak reliability in predicting behavior, there might be little reason to conduct them. Improved models of the behavior-attitude linkage are needed.

We have noted the generally atheoretic nature of much of the previous wilderness research. There remains a continuing need for theory building and testing. Yet it is important to recognize that it is unlikely there is any single theory most appropriate for the study of wilderness attitudes and behavior or, indeed, that there is any theoretical perspective applicable to wilderness as such. The study of the recreational use of wilderness could be undertaken at a variety of differing levels of analysis, ranging from general human behavior, leisure behavior, outdoor recreation behavior, resource-based recreation behavior, to wilderness recreation behavior. The appropriate and most useful theoretical orientation likely changes as one moves from one level of analysis to another. What, if any, is the most appropriate level of analysis?

Since European settlement of North America, America's attitudes toward, and behavior with regard to, wilderness have undergone many changes, from hostility and exploitation to wonder and enjoyment. Now as the period of major expansion of the National Wilderness Preservation System begins to reach its latter stages, it is more important than ever that we better understand our Nation's attitudes and behavior so that we might better learn to preserve these treasured areas.

REFERENCES

Absher, J. D.; Lee, R. G. Density as an incomplete cause of crowding in backcountry settings. Leisure Sciences. 4(3): 231-247; 1981.

Adelman, B. J.; Heberlein, T. A.; Bonnicksen, T. M. Social psychological explanations for the persistence of a conflict between paddling canoeists and motorcraft users in the Boundary Waters Canoe Area. Leisure Sciences. 5(1): 45-62; 1982.

Allen, D. J. Wilderness user preferences for psychological outcomes and setting attributes. Fort Collins, CO: Colorado State University; 1979. 123 p. Ph.D. dissertation.

Allin, Craig W. The politics of wilderness preservation. Westport, CT: Greenwood Press; 1982. 304 p.

Altman, I. The environment and social behavior. Monterey, CA: Brooks/Cole; 1975. 256 p.

Anderson, D. H. Displacement of visitors within the Boundary Waters Canoe Area Wilderness. Fort Collins, CO: Colorado State University; 1980. 138 p. Ph.D. dissertation.

Anderson, L. M.; Mollrgan, B. E.; Goodman, L. S. Esthetics of sound in outdoor settings. In: Southeastern recreation research conference: 1980-1981 proceedings; 1980 February 18-19; 1981 February 19-20; Asheville, NC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1982: 109-122.

Bassett, J. R.; Driver, B. L.; Schreyer, R. User study: characteristics and attitudes, Michigan's AuSable River. Rogers City, MI: Northeast Michigan Regional Planning and Development Commission; 1972. 147 p.

Baumgartner, R.; Gundry, K. The crowding literature: theory with no findings and findings with no theory.

Paper presented at the annual meeting of the Rural Sociological Society, San Fransisco, CA; 1978.

Beaulieu, J. T. An examination of the effect of environmental type on the way recreationists process information relating to recreation outcomes. Paper presented at the leisure research symposium, National Recreation and Parks Association, Kansas City, MO; 1983.

Beaulieu, J. T. Defining the components of environmental image for use as a predictor of decision to participate. Logan, UT: Utah State University; 1984. 171 p. Ph.D. dissertation.

Beaulieu, J. T.; Schreyer, R. An initial examination of environmental categorization by recreationists. Paper presented at the leisure research symposium, National Recreation and Parks Association, Louisville, KY; 1982.

Beaulieu, J. T.; Schreyer, R. Choices of wilderness environments—differences between real and hypothetical choice situations. In: Stankey, George H.; McCool, Stephen F., compilers. Proceedings—symposium on recreation choice behavior; 1984 March 22-23; Missoula, MT. General Technical Report INT-184. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985: 38-45.

Becker, R. H. Social carrying capacity and user satisfaction: an experiential function. Leisure Sciences. 1(3): 241-258; 1978.

Becker, R. H. Displacement of recreational users between the Lower St. Croix and Upper Mississippi Rivers. Journal of Environmental Management. 13: 259-267; 1981a.

Becker, R. H. User reaction to Wild and Scenic River designation. Water Resources Bulletin. 17(4): 623-626; 1981b.

Black, J. S.; Heberlein, T. A. Emergent norms and environmental action: reciprocal causation of personal and perceived social norms in the purchase of lead-free gasoline. Paper presented at the annual meeting of the Rural Sociological Society, San Francisco, CA; 1976.

Bowley, C. S. Motives, management preferences, and perceptions of crowding of backcountry hiking trail users in the Allegheny National Forest of Pennsylvania. State College, PA: Pennsylvania State University; 1979. 183 p. M.S. thesis.

Brown, P. J. Psychological benefits of outdoor recreation. In: Kelly, J. R., ed. Social benefits of outdoor recreation. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 13-17.

Brown, P. J.; Haas, G. E. Wilderness recreation experiences: the Rawah case. Journal of Leisure Research. 12(3): 229-241; 1980.

Buck, J. Vincent. Public involvement in the planning of Yosemite National Park. [No date]. Unpublished paper on file at: U.S. Department of the Interior, National Park Service, Yosemite National Park, CA. 31 p.

Buist, L.; Hoots, T. A. Recreation opportunity spectrum: application to resource planning. Journal of Forestry. 80(2): 84-86; 1982.

Bultena, G. L.; Field, D. R. Visitors to National Parks: a test of the elitism argument. Leisure Sciences. 1(4): 395-409; 1978.

Bultena, G. L.; Field, D. R. Structural effects in national parkgoing. Leisure Sciences. 3(3): 221-240; 1980.

Bultena, G. L.; Klessig, L. L. Satisfaction in camping: a conceptualization and guide to social research. Journal of Leisure Research. 1(4): 348-354; 1969.

Bultena, Gordon; Albrecht, Don; Womble, Peter. Freedom versus control: a study of backpackers' preferences for wilderness management. Leisure Sciences. 4(3): 297-310; 1981a.

Bultena, Gordon; Field, Donald; Womble, Peter; Albrecht, Don. Closing the gates: a study of backcountry use-limitation at Mount McKinley National Park. Leisure Sciences. 4(3): 249-267; 1981b.

Bultena, Gordon L.; Taves, Marvin J. Changing wilderness images and forestry policy. Journal of Forestry. 59(3): 167-171; 1961.

Burch, W. R., Jr. The play world of camping: research into the social meaning of outdoor recreation. American Journal of Sociology. 70(5): 604-612; 1965.

Burch, W. R., Jr. Wilderness—the life cycle and forest recreational choice. Journal of Forestry. 64(9): 606-610; 1966.

Burch, W. R., Jr. The ecology of metaphors—spacing regularities for humans and other primates in urban and wildland habitats. Leisure Sciences. 4(3): 213-230; 1981.

Burch, William R., Jr.; Wenger, Wiley D., Jr. The social characteristics of participants in three styles of family camping. Research Paper PNW-48. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1967. 29 p.

Callicott, J. B. Traditional American Indian and Western European attitudes toward nature: an overview. Environmental Ethics. 4(4): 293-318; 1982.

Cancian, F. M. What are norms? New York: Cambridge University Press; 1975. 256 p.

Canon, L. K.; Adler, S.; Leonard, R. E. Factors affecting dispersion of backcountry campers. Research Note NE-276. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1979. 6 p.

Carhart, Arthur. Recreation in the forest. American Forestry. 26(317): 268-272; 1920.

Carhart, Arthur. Timber in your life. Philadelphia: J. B. Lippincott; 1955. 317 p.

Catton, W. R., Jr. Motivations of wilderness users. Pulp and Paper Magazine of Canada. 1969 December 19: 121-126.

Cheek, N. H., Jr.; Burch, W. R., Jr. The social organization of leisure in human society. New York: Harper and Row; 1976. 283 p.

Cheek, N. H., Jr.; Field, D. R.; Burdge, R. J., eds. Leisure and recreation places. Ann Arbor, MI: Ann Arbor Science; 1976. 172 p.

Chesnutt, T. J. The effects of an adventure program and leadership experience upon anxiety. Paper presented at the leisure research symposium, National Recreation and Parks Association, Louisville, KY; 1982.

Churchill, J. Gods, frogs and sojourns: the experience of wilderness. Sound. Brooklyn, NY: Long Island University, Boston Center. 1982 Summer: 206-212.

Cockrell, D.; McLaughlin, W. J. Choosing a river to run: motives and preferences of river recreationists. Paper presented at the leisure research symposium, National Recreation and Parks Association, New Orleans, LA; 1979.

Cockrell, D.; McLaughlin, W. J. Social influences on wild river recreationists. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1982: 140-145.

Cole, David N.; Benedict, Jim. Wilderness campsite selection—what should users be told? Park Science. 3(4): 5-7; 1983.

Cole, David N.; Dalle-Molle, John. Managing campfire impacts in the backcountry. General Technical Report INT-135. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 16 p.

Copp, J. H. Discussion of wildernism—the development, dimensions and use of an attitude scale. Paper presented at the annual meeting of the Rural Sociological Society, San Francisco, CA; 1967.

Crandall, Rick. Motivations for leisure. Journal of Leisure Research. 12(1): 45-54; 1980.

Daniel, T. C. Psychological perspectives on air quality and visibility in parks and wilderness areas. In: Proceedings—workshop in visibility values. General Technical Report WO-18. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 84-92.

Daniel, T. C.; Vining, J. Methodological issues in the assessment of landscape quality. In: Altman, I.; Wohlwill, J. F., eds. Behavior and the natural environment. New York: Plenum; 1983: 39-84.

Dawson, C. P.; Decker, D. J.; Lime, D. W.; Knopf, R. C. Characteristics and management preferences of 1979 summer river recreationists on the Upper Delaware River. Natural Resource Research and Extension Series 15. Ithaca, NY: Cornell University Agriculture Experiment Station; 1981. 31 p.

Dawson, C. P.; Decker, D. J.; Smolka, R. A. Management preferences of boaters and landowners along the Upper Delaware Scenic and Recreational River. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1982: 14-19.

Dearden, Philip; Sewell, W. R. Derrick. From gloom to glory and beyond: the North American mountain recreation experience. In: Bayfield, M. G.; Barrow, G. C., eds. The ecological impacts of outdoor recreation on mountain areas in Europe and North America: Proceedings of a symposium; 1983 September 9-12; Ambleside, Cumbria, Great Britain. R.E.R.G. Report 9. Wye, Kent, Great Britain: Recreation Ecology Research Group, Wye College; 1985: 1-12.

Devall, W. Social worlds of leisure. In: Cheek, N. H., Jr.; Field, D. R.; Burdge, R. J., eds. Leisure and recreation places. Ann Arbor, MI: Ann Arbor Science; 1976: 131-142.

Ditton, R. B. The Buffalo National River recreation study: year one. College Station, TX: Texas A. & M. University, Texas Agriculture Experiment Station; 1979. 115 p.

Ditton, R. B. The Buffalo National River recreation study: year two. College Station, TX: Texas A. & M. University, Texas Agriculture Experiment Station; 1981. 192 p.

Ditton, R. B.; Fedler, A. J.; Graefe, A. R. Factors contributing to perceptions of recreation crowding. Leisure Sciences. 5(4): 273-286; 1983.

Ditton, R. B.; Fedler, A. J.; Holland, S. M. A survey and analysis of use patterns in Santa Elena Canyon (Big Bend National Park) during Thanksgiving vacation period 1980. College Station, TX: Texas A. & M. University, Texas Agriculture Experiment Station; 1981. 40 p.

Ditton, R. B.; Fedler, A. J.; Holland, S. M.; Graefe, A. R. A user/setting approach to understanding recreational experiences. In: Southeastern recreation research conference, 1980-1981 proceedings; 1980 February 18-19; 1981 February 19-20; Asheville, NC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1982: 237-252.

Douglas, D. The spirit of wilderness and the religious community. Sierra. 68(3): 56-57; 1983.

Downing, K.; Clark, R. N. Users' and managers' perceptions of dispersed recreation impacts: a focus on roaded forest lands. In: Ittner, R.; Potter, D. R.; Agee, J. K.; Anschell, S., eds. Recreational impacts on wildlands—conference proceedings; 1978 October 27-29; Seattle, WA. No. R-6-001-1979. Seattle, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 18-23.

Driver, B. L. Toward a better understanding of the social benefits of outdoor recreation participation. In: Proceedings of the southern States recreation research applications workshop; 1975 September 15-18; Asheville, NC. General Technical Report SE-9. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1976: 163-189.

Driver, B. L.; Bassett, J. R. Defining conflicts among river users: a case study of Michigan's AuSable River. Naturalist. 26: 19-23; 1975.

Driver, B. L.; Brown, P. J. A social-psychological definition of recreation demand, with implications for recreation resource planning. In: Assessing demand for outdoor recreation. Washington, DC: National Academy of Sciences; 1975: 63-88.

Driver, B. L.; Brown, P. J. The opportunity spectrum concept and behavioral information in outdoor recreation resource supply inventories: a rationale. In: Integrated inventories of renewable natural resources. General Technical Report RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1978: 24-31.

Driver, B. L.; Cooksey, R. W. Preferred psychological outcomes of recreational fishing. In: Barnhart, R. A.; Roelofs, T. D., eds. Catch and release fishing as a management tool. Arcata, CA: Humboldt State University; 1977: 27-40.

Driver, B. L.; Greene, P. Man's nature: innate determinants of response to natural environments. In: Children, nature, and the urban environment: proceedings of a symposium-fair; 1975 May 19-23; Washington, DC. General Technical Report NE-30. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977: 63-70.

Driver, B. L.; Knopf, R. C. Temporary escape: one product of sport fisheries management. Fisheries. 1: 21-29; 1976.

Driver, B. L.; Knopf, R. C. Personality, outdoor recreation and expected consequences. Environment and Behavior. 9(2): 169-193; 1977.

Echelberger, Herbert E.; Moeller, George H. Use and users of the Cranberry Backcountry in West Virginia: insights for eastern backcountry management. Research Paper NE-363. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p.

Erickson, K. Ceremonial landscapes. Landscape. 22(1): 39; 1977.

Ewert, A. Why people climb: a factor discriminate analysis. Paper presented at the leisure research symposium, National Recreation and Parks Association, Orlando, FL; 1984.

Fazio, James R. Communicating with the wilderness user. Wildlife and Range Science Bulletin 28. Moscow, ID: University of Idaho, College of Forestry; 1979a. 65 p.

Fazio, James R. Information and education techniques to improve minimum impact use knowledge in wilderness areas. In: Ittner, R.; Potter, D. R.; Agee, J. K.; Anschell, S., eds. Recreational impacts on wildlands—conference proceedings; 1978 October 27-29; Seattle, WA. No. R-6-001-1979. Seattle, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979b: 227-233.

Fazio, James R.; Gilbert, Douglas L. Mandatory wilderness permits: some indications of success. Journal of Forestry. 72(12): 753-756; 1974.

Fazio, James R.; Gilbert, Douglas L. Public relations and communications for natural resource managers. Dubuque, IA: Kendall/Hunt Publishing Co.; 1981. 375 p.

Feingold, B. H. The wilderness experience: the interaction of person and environment. Berkeley, CA: California School of Professional Psychology; 1979. 208 p. Ph.D. dissertation.

Field, D. R. The social organization of recreation places. In: Cheek, N. H., Jr.; Field, D. R.; Burdge, R. J., eds. Leisure and recreation places. Ann Arbor, MI: Ann Arbor Science; 1976: 19-30.

Field, D. R.; Cheek, N. H., Jr. A basis for assessing differential participation in water-based recreation. Water Resources Bulletin. 10(6): 1218-1227; 1974.

Field, D. R.; O'Leary, J. T. Social groups as a basis for assessing participation in selected water activities. Journal of Leisure Research. 5(1): 16-25; 1973.

Field Research Corporation. California public opinion and behavior regarding the California desert. Technical Report. San Francisco, CA; 1977. [Pages unknown].

Fischer, R. A cartography of the ecstatic and meditative states. Science. 174: 897-904; 1971.

Fishbein, M.; Ajzen, I. Belief, attitude, intention and behavior: an introduction to theory and research. Reading, MA: Addison-Wesley; 1975. 578 p.

Foster, R. J.; Jackson, E. L. Factors associated with camping satisfaction in Alberta Provincial Park campgrounds. Journal of Leisure Research. 4(3): 292-306; 1979.

Frissell, S. S.; Duncan, D. P. Campsite preference and deterioration in the Quetico-Superior canoe country. Journal of Forestry. 63(4): 256-260; 1965.

Frissell, Sidney S.; Stankey, George H. Wilderness environmental quality: search for social and ecological harmony. In: Proceedings of the 1972 national Society of American Foresters convention; 1972 October 1-5; Hot Springs, AR. Washington, DC: Society of American Foresters; 1972: 170-183.

Gillette, J. H. A study of attitude changes as a result of Outward Bound Mountain Ski School. Greeley, CO: University of Northern Colorado; 1979. 197 p. Ph.D. dissertation.

Graber, Linda H. Wilderness as sacred space. Washington, DC: Association of American Geographers; 1976. 124 p.

Graefe, A. R.; Elements of motivation and satisfaction in the float trip experience in Big Bend National Park. College Station, TX: Texas A. & M. University; 1977. 170 p. M.S. thesis.

Graefe, A. R. Understanding diverse fishing groups: the case of drum fishermen. In: Marine recreational fisheries. VI. Washington, DC: The Sport Fishing Institute; 1981: 69-79.

Graefe, A. R.; Vaske, J. J.; Kuss, F. R. Social carrying capacity: an integration and synthesis of twenty years of research. Leisure Sciences. 6(4): 395-432; 1984.

Gramann, J. H. Toward a behavioral theory of crowding in outdoor recreation: an evaluation and synthesis of research. Leisure Sciences. 5(2): 109-126; 1982.

Gramann, J. H.; Burdge, R. J. The effects of recreation goals on conflict perception: the case of water skiers and fishermen. Journal of Leisure Research. 13(1): 15-27; 1981.

Haas, G. E. User preferences for recreation experience opportunities and physical resource attributes in three Colorado wilderness areas. Fort Collins, CO: Colorado State University; 1979. 152 p. Ph.D. dissertation.

Haas, G. E.; Driver, B. L.; Brown, P. J. A study of ski touring experience on the White River National Forest. In: Proceedings, North American symposium on dispersed winter recreation; 1980 February 27-29; St. Paul, MN. Office of Special Programs-Educational Series 2-3. St. Paul, MN: University of Minnesota, Agricultural Extension Service; 1980a: 25-30.

Haas, G. E.; Driver, B. L.; Brown, P. J. Measuring wilderness recreation experiences. In: Proceedings—wilderness psychology group annual conference; 1980 August 14-15; Durham, NH. Durham, NH: University of New Hampshire; 1980b: 20-40.

Hahn, M. J. The visual decision-making process as a technique for redistribution of outdoor recreation use. Logan, UT: Utah State University; 1982. 111 p. M.S. thesis.

Hammitt, W. E. Cognitive dimensions of wilderness solitude. Environment and Behavior. 14(4): 478-493; 1982.

Hammitt, W. E. Cognitive states of well-being in recreational environments. Paper presented at the leisure research symposium, National Recreation and Parks Association, Orlando, FL; 1984.

Hammitt, W. E.; Brown, G. F. Functions of privacy in wilderness environments. Leisure Sciences. 6(2): 151-166; 1984.

Hammitt, W. E.; Loy, J. L. A comparison of winter and summer backcountry user behavior. Paper presented at the leisure research symposium, National Recreation and Parks Association, Louisville, KY; October 24-27, 1982.

Hammitt, W. E.; McDonald, C. D. Social group participation and its importance as a variable in examining management control preferences of stream floaters. In: Southeastern recreation research conference, 1980-1981 proceedings; 1980 February 18-19; 1981 February 19-20; Asheville, NC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1982: 227-236.

Hammitt, W. E.; McDonald, C. D.; Noe, F. P. Use level and encounters: important variables of perceived crowding among non-specialized recreationists. Journal of Leisure Research. 16(1): 1-8; 1984.

Hampton, H. Duane. How the U.S. cavalry saved our national parks. Bloomington, IN: Indiana University Press; 1971. 246 p.

Hardin, Garrett. The economics of wilderness. Natural History. 78(6): 20-27; 1969.

Harris, C. C. Recreation satisfaction: visitor evaluation of forest recreation experiences as a decision-making process. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1982: 160-163.

Hautaluoma, J; Brown, P. J. Attributes of the deer hunting experience: a cluster analytic study. Journal of Leisure Research. 10(4): 271-278; 1978.

Hautaluoma, J. E.; Brown, P. J.; Battle, N. L. Elk hunter consumer satisfaction patterns. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1982: 74-80.

Heaps, R.; Thorstenson, C. Self-concept changes immediately and one year after survival training. Therapeutic Recreation Journal. 8(2): 60-63; 1974.

Heberlein, T. A. Social psychological assumptions of user attitude surveys: the case of the wildernism scale. Journal of Leisure Research. 5(1): 18-33; 1973.

Heberlein, T. A. Density, crowding and satisfaction: sociological studies for determining carrying capacities. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 67-76.

Heberlein, T. A.; Dunwiddie, P. Systematic observation of use levels, campsite selection and visitor characteristics at a high mountain lake. Journal of Leisure Research. 11(4): 307-316; 1979.

Heberlein, T. A.; Laybourne, B. The Wisconsin deer hunter: social characteristics, attitudes and preferences for proposed hunting season changes. Working Paper 10. Madison, WI: University of Wisconsin-Madison, College of Agricultural and Life Sciences, School of Natural Resources, Center for Resource Policy Studies; 1978. 96 p.

Heberlein, T. A.; Shelby, B. Carrying capacity, values and the satisfaction model: a reply to Greist. Journal of Leisure Research. 9(2): 142-148; 1977.

Heberlein, T. A.; Vaske, J. J. Crowding and visitor conflict on the Bois Brule River. Technical Report WIS WRC 77-04. Madison, WI: University of Wisconsin, Water Resource Center; 1977. 109 p.

Heberlein, T. A.; Trent, J. N.; Baumgartner, R. M. The influence of hunter density on firearm deer hunters' satisfaction: a field experiment. In: Sabol, K., ed. Transactions, 47th North American wildlife and natural resources conference; 1982 March 26-31; Portland, OR. Washington, DC: Wildlife Management Institute; 1982: 665-676.

Heberlein, Thomas A.; Black, J. Stanley. Attitudinal specificity and the prediction of behavior in a field setting. Journal of Personality and Social Psychology. 33(4): 474-479; 1976.

Hendee, J. C.; Roggenbuck, J. W. Wilderness related education as a factor increasing demand for wilderness. Paper presented at the international forest congress convention, Quebec City, Canada; 1984.

Hendee, John C.; Harris, Robert W. Foresters' perception of wilderness user attitudes and preferences. Journal of Forestry. 68(12): 759-762; 1970.

Hendee, John C.; Pyle, Robert M. Wilderness managers, wilderness users: a problem of perception. The Naturalist. 22(3): 22-26; 1971.

Hendee, John C.; Catton, William R., Jr.; Marlow, Larry D.; Brockman, C. Frank. Wilderness users in the Pacific Northwest: their characteristics, values and management preferences. Research Paper PNW-61. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968. 92 p.

Hendee, John C.; Clark, Roger N.; Dailey, Thomas E. Fishing and other recreation behavior at high mountain lakes in Washington State. Research Note PNW-304. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1977. 27 p.

Hendee, John C.; Stankey, George H.; Lucas, Robert C. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 381 p.

Herzberg, F. The managerial choice. Homewood, IL: Dow Jones, Irwin; 1976. 360 p.

Hollender, J. W. Motivational dimensions of the camping experience. Journal of Leisure Research. 9(2): 133-141; 1977.

Hunt, J. D. Image as a factor in tourism. Journal of Travel Research. 13(1): 1-7; 1975.

Huth, Hans. Nature and the American: three centuries of changing attitudes. Berkeley, CA: University of California Press; 1957. 250 p.

Ip, Po-Keng. Taoism and the foundation of environmental ethics. Environmental Ethics. 5(4): 335-343; 1983.

Jacob, G. R.; Schreyer, R. Conflict in outdoor recreation: a theoretical perspective. Journal of Leisure Research. 12(4): 368-380; 1980.

Kaplan, R. Some psychological benefits of an outdoor challenge program. Environment and Behavior. 6(1): 101-116; 1974.

Kaplan, R. Wilderness perception and psychological benefits: an analysis of a continuing program. Leisure Sciences. 6(3): 271-290; 1984.

Kaplan, S. Tranquility and challenge in the natural environment. In: Children, nature, and the urban environment: proceedings of a symposium-fair; 1975 May 19-23; Washington, DC. General Technical Report NE-30. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977: 181-185.

Kaplan, S.; Talbot, J. F. Psychological benefits of a wilderness experience. In: Altman, I.; Wohlwill, J. F., eds. Behavior and the natural environment. New York: Plenum; 1983: 163-203.

Kariel, H. G. Mountaineers and the general public: a comparison of their evaluation of sounds in a recreational environment. Leisure Sciences. 3(2): 155-167; 1980.

Kennedy, James J.; Brown, Perry J. Attitudes and behavior of fishermen of Utah's Uinta Primitive Area. Fisheries. 1(6): 15-17, 30-31; 1976.

Klausner, S. Z. The intermingling of pain and pleasure: the stress-seeking personality in its social context. In: Klausner, S. Z., ed. Why man takes chances: studies in stress seeking. Garden City, NY: Doubleday and Company; 1968: 59-73.

Knopf, R. C. Management problems in river recreation—what river floaters are telling us. Naturalist. 33(2): 12-17; 1982.

Knopf, R. C. Recreational needs and behavior in natural settings. In: Altman, I.; Wohlwill, J. F., eds. Behavior and the natural environment. New York: Plenum; 1983: 205-240.

Knopf, R. C.; Driver, B. L. A problem solving approach to recreation behavior. Paper presented at the seventy-seventh annual meeting, Michigan Academy of Science, Arts and Letters, Ann Arbor, MI; 1972. 21 p.

Knopf, R. C.; Driver, B. L.; Bassett, J. R. Motivations for fishing. In: Trefethen, J. B., ed. Transactions of the 38th North American wildlife and natural resources conference; 1973 March 18-21; Washington, DC. Washington, DC: Wildlife Management Institute; 1973: 191-204.

Knopf, R. C.; Peterson, G. L.; Leatherberry, E. C. Motives for recreational river floating: relative consistency across settings. Leisure Sciences. 5(3): 231-255; 1983.

Knopp, T. B.; Leatherberry, E. C. Choosing and allocating outdoor recreation opportunities: the decision process. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 89-93.

Krumpe, E. E. Redistributing backcountry use by a behaviorally based communications device. Fort Collins, CO: Colorado State University; 1979. 156 p. Ph.D. dissertation.

Krumpe, E. E.; Brown, P. J. Redistributing backcountry use through information related to recreation experience. Journal of Forestry. 80(6): 360-362; 1982.

Krumpe, E. E.; McLaughlin, W. J. A model of recreationists' decision-making process. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 94-99.

Krutch, J. W. Grand Canyon: today and all its yesterdays. New York: William Morrow and Company; 1958. 256 p.

Lawler, E. E. Motivation in work organizations. Monterey, CA: Brooks/Cole; 1973. 224 p.

Lee, R. G. The social definition of outdoor recreation places. In: Burch, W. R., Jr.; Cheek, N. H., Jr.; Taylor, L., eds. Social behavior, natural resources and the environment. New York: Harper and Row; 1972: 68-84.

Lee, R. G. The management of human components in the Yosemite National Park ecosystem. Yosemite, CA: The Yosemite Institute; 1975. 134 p.

Lee, R. G. Alone with others: the paradox of privacy in wilderness. Leisure Sciences. 1(1): 3-19; 1977.

Leopold, Aldo. Wilderness as a form of land use. Journal of Land and Public Utility Economics. 1(4): 398-404; 1925.

Leopold, L. B. Quantitative comparison of some aesthetic factors among rivers. Circular 620. Washington, DC: U.S. Geological Survey; 1969. 16 p.

Lime, D. W. Physical resource and social determinants of whitewater river recreation and some implications of those conditions for visitor management. In: Royer, L. E.; Becker, W. H.; Schreyer, R., eds. Managing Colorado River whitewater—the carrying capacity strategy. Logan, UT: Utah State University, Institute of Outdoor Recreation and Tourism; 1977: 146-155.

Lime, D. W.; Buchman, G. Putting wilderness permit information to work. Journal of Forestry. 72(10): 622-626; 1974.

Lime, David W. Large groups in the Boundary Waters Canoe Area—their numbers, characteristics, and impact. Research Note NC-142. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1972. 4 p.

Lime, David W.; Lucas, Robert C. Good information improves the wilderness experience. Naturalist. 28(4): 18-20; 1977.

Lowenthal, David. The American scene. Geographical Review. 58: 61-88; 1968.

Lucas, Robert C. User concepts of wilderness and their implications for resource management. In: Western resource papers 1964—new horizons for resources research. Boulder, CO: University of Colorado Press; 1964a: 29-39.

Lucas, Robert C. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Natural Resources Journal. 3(3): 394-411; 1964b.

Lucas, Robert C. Hikers and other trail users. In: The forest recreation symposium proceedings; 1971 October 12-14; Syracuse, NY. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1971: 113-122.

Lucas, Robert C. Wilderness: a management framework. Journal of Soil and Water Conservation. 28(4): 150-154; 1973.

Lucas, Robert C. Perceptions of non-motorized recreational impacts: a review of research. In: Ittner, R.;

Potter, D. R.; Agee, J. K.; Anschell, S., eds. Recreational impacts on wildlands—conference proceedings; 1978 October 27-29; Seattle, WA. No. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 24-31.

Lucas, Robert C. Use patterns and visitor characteristics, attitudes and preferences in nine wilderness and other roadless areas. Research Paper INT-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 90 p.

Lucas, Robert C. Redistributing wilderness use through information supplied to visitors. Research Paper INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 15 p.

Lucas, Robert C. Visitor characteristics, attitudes, and use patterns in the Bob Marshall Wilderness complex, 1970-82. Research Paper INT-345. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 32 p.

Magill, A. W. Dispersal of recreationists on wildlands. In: Outdoor recreation research: applying the results. General Technical Report NC-9. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1974: 92-97.

Manfredo, M. J. Wilderness experience opportunities and management preferences for three Wyoming wilderness areas. Fort Collins, CO: Colorado State University; 1979. 113 p. Ph.D. dissertation.

Manfredo, Michael J.; Brown, Perry J.; Haas, Glenn E. Fisherman values in wilderness. In: Proceedings of the Western Association of Fish and Wildlife Agencies and the Western Division of the American Fisheries Society; 1978; San Diego, CA. [Place of publication unknown]; 1978: 276-298.

Marshall, Robert. The problem of wilderness. Scientific Monthly. 30: 141-148; 1930.

Maslow, A. Toward a psychology of being. 2d ed. Princeton, NJ: Van Nostrand; 1968. 240 p.

Matheny, S. J. A successful campaign to reduce trail switchback shortcutting. In: Ittner, R.; Potter, D. R.; Agee, J. K.; Anschell, S., eds. Recreational impacts on wildlands—conference proceedings; 1978 October 27-29; Seattle, WA. No. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 217-221.

McCloskey, Michael. The Wilderness Act of 1964: its background and meaning. Oregon Law Review. 45: 288-321; 1966.

McCool, S. F. Does wilderness designation lead to increased recreational use? Journal of Forestry. 83(1): 38-41; 1985.

McCool, S. F.; Haydock, S. M. Hikers of the Virgin River Narrows. Logan, UT: Utah State University, Institute of Outdoor Recreation and Tourism; 1976. 82 p.

McCool, S. F.; Petersen, M. An application of the two factor theory of satisfaction to recreational settings. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; Technical Report; 1982. 28 p.

McCool, Stephen F.; Stankey, George H. Visitor attitudes toward wilderness fire management policy—1971-84. Research Paper INT-357. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 7 p.

McDonald, C. D.; Hammitt, W. E. Use patterns, preferences and social impacts of floaters on river resources in the Southern Appalachian region. Knoxville, TN: University of Tennessee; 1979. 241 p.

McDonough, M. H. The influence of place on recreation behavior: an ecological perspective. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 120-123.

McLaughlin, W. J.; Paradice, W. E. J. Using visitor preference information to guide dispersed winter recreation management for cross-country skiing and snowmobiling. In: Proceedings, North American symposium on dispersed winter recreation; 1980 February 27-29; St. Paul, MN. Office of Special Programs-Educational Series 2-3. St. Paul, MN: University of Minnesota, Agricultural Extension Service; 1980: 64-72.

McLaughlin, W. J.; Krumpe, E. E.; Paradice, W. E. J. Do river floaters perceive river segments differently? should managers? In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 7-13.

Meier, J. F.; Morash, T. W.; Welton, G. E., eds. High adventure outdoor pursuits: organization and leadership. Salt Lake City, UT: Brighton Publishing Company; 1980. 232 p.

Merriam, L. C., Jr.; Ammons, R. B. The wilderness user in three Montana areas. St. Paul, MN: University of Minnesota, School of Forestry; 1967. 54 p.

More, T. A. Attitudes of Massachusetts hunters. In: Hendee, J. C.; Schoenfeld, C., eds. Human dimensions in wildlife programs. Washington, DC: Wildlife Management Institute; 1973: 72-76.

Murray, Judith Buckley. Appalachian trail users in the southern national forests: their characteristics, attitudes, and management preferences. Research Paper SE-116. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1974. 19 p.

Nash, Roderick. Wilderness and the American mind. 3d ed. New Haven, CT: Yale University Press; 1982. 425 p.

Nielsen, J. M.; Endo, R. Where have all the purists gone? An empirical examination of the displacement process hypothesis in wilderness recreation. Western Sociological Review. 8: 61-75; 1977.

Nielsen, J. M.; Shelby, B. River-running in the Grand Canyon: how much and what kind of use? In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 168-177.

Nielsen, J. M.; Shelby, B.; Hass, J. E. Sociological carrying capacity and the last settler syndrome. Pacific Sociological Review. 20: 568-581; 1977.

O'Leary, J. T.; Field, D. R.; Schreuder, G. Social groups and water activity clusters: an exploration of interchangeability and substitution. In: Field, D. R.; Barron, J. C.; Long, B. F., eds. Water and community development: social and economic perspectives. Ann Arbor, MI: Ann Arbor Science; 1974: 195-215.

Olson, S. The spiritual aspects of wilderness. In: Schwartz, W., ed. Voices for the wilderness. New York: Ballantine Books; 1969: 131-142.

Olson, S. F. The singing wilderness. New York: Alfred Knopf; 1956. 244 p.

Outdoor Recreation Resources Review Commission [ORRRC]. Wilderness and recreation—a report on resources, values and problems. ORRRC Study Report No. 3. Washington, DC: U.S. Government Printing Office; 1962. 352 p.

Peterson, G. L. A comparison of the sentiments and perception of canoeists and wilderness managers in the Boundary Waters Canoe Area. Journal of Leisure Research. 6(3): 194-206; 1974a.

Peterson, G. L. Evaluating the quality of the wilderness environment: congruence between perception and aspiration. Environment and Behavior. 6(2): 169-193; 1974b.

Peterson, G. L.; Lime, D. W. Two sources of bias in the measurement of human response to the wilderness environment. Journal of Leisure Research. 5(1): 66-73; 1973.

Peterson, Max. National Forest dimensions and dilemmas. In: Frome, Michael, ed. Issues in wilderness management: Proceedings of the national wilderness workshop; 1983 October; Moscow, ID. Boulder, CO: Westview Press; 1985: 36-52.

Pfister, R. D.; Frenkel, R. Field investigation of river use within the wild river area of the Rogue River, Oregon. 1974. Interim report to Oregon State Marine Board, Salem, OR. 112 p.

Poore, Duncan; Gryne-Ambroes, Paule. Nature conservation in northern and western Europe. Gland, Switzerland: International Union for Conservation of Nature; 1980. 408 p.

Probst, D. B.; Lime, D. W. How satisfying is satisfaction research? A look where we are going. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 124-133.

Reed, H. P. A prestige hierarchy of recreation land classification. Logan, UT: Utah State University; 1973. 44 p. M.S. thesis.

Rentz, L. H.; Schreyer, R. Park visitor responses to low risk natural hazards. Logan, UT: Utah State University, Institute of Outdoor Recreation and Tourism; 1977. 143 p.

Robertson, R. D. Visitor knowledge affects visitor behavior. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 49-51.

Roggenbuck, J. W. Socio-psychological inputs into carrying capacity assessments for float-trip use of whitewater rivers in Dinosaur National Monument. Logan, UT: Utah State University; 1975. 309 p. Ph.D. dissertation.

Roggenbuck, J. W.; Berrier, D. L. Communications to disperse wilderness campers. Journal of Forestry. 79(5): 295-297; 1981.

Roggenbuck, J. W.; Berrier, D. L. A comparison of the effectiveness of two communication strategies in dispersing wilderness campers. Journal of Leisure Research. 14(1): 77-89; 1982.

Roggenbuck, J. W.; Kienast, C. R.; Middaugh, G. B. Quality recreation in wilderness. In: Brown, P. J.; Schomaker, J. H., eds. Recreation carrying capacity in wilderness—a series of topical papers. Logan, UT: Utah State University, Institute of Outdoor Recreation and Tourism; 1973: 1-12.

Roggenbuck, Joseph W.; Schreyer, Richard M. Relations between river trip motives and perception of crowding, management preference, and experience satisfaction. In: Proceedings, river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 359-364.

Roggenbuck, Joseph W.; Watson, Alan E.; Stankey, George H. Wilderness management in the Southern Appalachians. Southern Journal of Applied Forestry. 6(3): 147-152; 1982.

Rossman, B. B.; Ulehla, Z. J. Psychological reward values associated with wilderness use: a functional reinforcement approach. Environment and Behavior. 9(1): 41-65; 1977.

Schmidt, D.; Keating, J. Human crowding and personal control: an integration of research. Psychological Bulletin. 36(4): 680-700; 1979.

Schomaker, J. H. Effect of selected information on dispersal of wilderness recreationists. Fort Collins, CO: Colorado State University; 1975. 103 p. Ph.D. dissertation.

Schreyer, R. Sociological and political factors in carrying capacity decision-making. In: Proceedings, third resources management conference; 1976 April 29-30; Fort Worth, TX. Santa Fe, NM: U.S. Department of the Interior, National Park Service, Southwest Region; 1976: 228-258.

Schreyer, R. Principles of recreational carrying capacity. In: Proceedings, first annual national conference in recreation planning and development. Vol. I. New York: American Society of Civil Engineers; 1979: 261-269.

Schreyer, R. Succession and displacement in river recreation. Research Project Paper 1901-78-07. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1980. 45 p.

Schreyer, R. Where have all the wildlands gone? some thoughts on the future of dispersed forest recreation. Western Wildlands. 7(2): 6-9; 1981.

Schreyer, R. Experience level affects expectations for participation. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 154-159.

Schreyer, R.; Downing, K. B. Four wheel drive impacts in Canyonlands National Park—Part II. User characteristics. Logan, UT: Utah State University, Institute of Outdoor Recreation and Tourism; 1980. 57 p.

Schreyer, R.; Jacob, G. R.; White, R. G. Environmental meaning as a determinant of spatial behavior in recreation. In: Frazier, J. W.; Epstein, B. J., eds. Proceedings of applied geography conference; 1981 October 24-25; Tempe, AZ. Vol. IV. Tempe, AZ: Association of Applied Geographers; 1981: 294-300.

Schreyer, R.; Lime, D. W. A novice isn't necessarily a novice. Leisure Sciences. 6(2): 131-149; 1984.

Schreyer, R.; Lime, D. W.; Williams, D. R. Characterizing the influence of past experience on recreation behavior. Journal of Leisure Research. 16(1): 34-50; 1984.

Schreyer, R.; Roggenbuck, J. W. The influence of experience expectations on crowding perceptions and social psychological carrying capacities. Leisure Sciences. 1(4): 373-394; 1978.

Schreyer, R.; Roggenbuck, J. W. Visitor images of National Parks: the influence of social definitions of places upon perceptions and behavior. In: Proceedings of the second conference on scientific research in the National Parks. Vol. 6. Washington, DC: U.S. Department of the Interior, National Park Service; 1980: 460-477.

Schreyer, R.; Roggenbuck, J. W.; McCool, S. F.; Royer, L. E.; Miller, J. The Dinosaur National Monument whitewater river recreation study. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation, Institute for the Study of Outdoor Recreation and Tourism; 1976. 165 p.

Schreyer, R.; White, R. G. A conceptual model of high risk recreation. In: Proceedings, first annual national conference in recreation planning and development. Vol. I. New York: American Society of Civil Engineers; 1979: 191-194.

Schreyer, R.; White, R. G.; McCool, S. F. Common attributes uncommonly exercised. Leisure Today (Journal of Physical Education and Recreation). 49(4): 12-14; 1978.

Schreyer, Richard; Nielson, Martin L. Westwater and Desolation Canyons: whitewater river recreation study. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation, Institute for the Study of Recreation; 1978. 196 p.

Scott, Neil R. Toward a psychology of wilderness experience. Natural Resources Journal. 14(2): 231-237; 1974.

Sessoms, H. D.; Stevenson, J. L. Leadership and group dynamics in recreation services. Boston: Allyn and Bacon; 1981. 284 p.

Shafer, E. L., Jr.; Mietz, J. Aesthetic and emotional experiences rate high with Northeast wilderness hikers. Environment and Behavior. 1(2): 187-197; 1969.

Shelby, B. Social psychological effects of crowding in wilderness: the case of river trips in the Grand Canyon. Boulder, CO: University of Colorado; 1976. 193 p. Ph.D. dissertation.

Shelby, B.; Nielsen, J. M. Use levels and user satisfaction in the Grand Canyon. Paper presented at the annual meeting of the Rural Sociological Society, San Fransisco, CA; 1975.

Shelby, Bo. Contrasting recreational experiences: motors and oars in the Grand Canyon. Journal of Soil and Water Conservation. 35(3): 129-131; 1980a.

Shelby, Bo. Crowding models for backcountry recreation. Land Economics. 56(1): 43-55; 1980b.

Shelby, Bo. Encounter norms in backcountry settings: studies of three rivers. Journal of Leisure Research. 13(2): 129-138; 1981a.

Shelby, Bo. Research, politics, and resource management decisions: a case study of river research in Grand Canyon. Leisure Sciences. 4(3): 281-296; 1981b.

Shelby, Bo; Colvin, Richard B. Determining use levels for the Rogue River. WRRI-63. Corvallis, OR: Oregon State University, Water Resources Research Institute; 1979. 27 p.

Shelby, Bo; Danley, Mark S.; Gibbs, Kenneth C.; Petersen, Margaret E. Preferences of backpackers and river runners for allocation techniques. Journal of Forestry. 80(7): 416-419; 1982.

Stankey, George H. Myths in wilderness decision-making. Journal of Soil and Water Conservation. 26(5): 183-188; 1971a.

Stankey, George H. The perception of wilderness recreation carrying capacity: a geographic study in natural resource management. East Lansing, MI: Michigan State University; 1971b. 351 p. Ph.D. dissertation.

Stankey, George H. A strategy for the definition and management of wilderness quality. In: Krutilla, J. V., ed. Natural environments—studies in theoretical and applied analysis. Baltimore, MD: Johns Hopkins University Press; 1972: 88-114.

Stankey, George H. Visitor perception of wilderness recreation carrying capacity. Research Paper INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 61 p.

Stankey, George H. Wilderness fire policy: an investigation of visitor knowledge and beliefs. Research Paper INT-180. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 17 p.

Stankey, George H. A framework for social behavioral research—applied issues. In: Burch, William R., Jr., ed. Long distance trails—the Appalachian Trail as a guide to future research and management needs. New Haven, CT: Yale University, School of Forestry and Environmental Studies; 1979a: 43-53.

Stankey, George H. Use rationing in two California wildernesses. Journal of Forestry. 77(5): 347-349; 1979b.

Stankey, George H. A comparison of carrying capacity perceptions among visitors to two wildernesses. Research Paper INT-242. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 34 p.

Stankey, George H.; Baden, John. Rationing wilderness use: methods, problems, and guidelines. Research Paper INT-192. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 20 p.

Stankey, George H.; Lucas, Robert C.; Lime, David W. Crowding in parks and wilderness. Design and Environment. 7(3): 38-41; 1976.

Stankey, George H.; McCool, Stephen F. Carrying capacity in recreational settings: evolution, appraisal and application. Leisure Sciences. 6(4): 453-474; 1984.

Stankey, George H.; McCool, Stephen F., compilers. Proceedings—symposium on recreation choice behavior; 1984 March 22-23; Missoula, MT. General Technical Report INT-184. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 106 p.

Stynes, D. J. The role of information in recreation site selection. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 100-104.

Tarbet, Don; Moeller, George H.; McLoughlin, Keven T. Attitudes of Salmon River users toward management of wild and scenic rivers. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 365-371.

Thorstenson, C. T.; Heaps, R. Outdoor survival and its implications for rehabilitation. Therapeutic Recreation Journal. 7(1): 31-33; 1973.

Thorstenson, C. T.; Heaps, R.; Snow, R. The effect of a twenty-nine day wilderness survival experience on anxiety and hearing sensitivity. Therapeutic Recreation Journal. 9(3): 117-120; 1975.

Titre, J. P.; Mills, A. S. Effect of encounters on perceived crowding and satisfaction. In: Lime, D. W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agriculture Experiment Station; 1982: 146-153.

Tuan, Y. F. Topophilia: a study of environmental perception, attitudes, and values. Englewood Cliffs, NJ: Prentice-Hall; 1974. 260 p.

Twight, B. W.; Smith, K. L.; Wissinger, G. H. Privacy and camping: closeness to the self vs. closeness to others. Leisure Sciences. 4(4): 427-441; 1981.

Ulrich, R. S. Aesthetic and affective response to natural environment. In: Altman, I.; Wohlwill, J. F., eds. Behavior and the natural environment. New York: Plenum; 1983: 85-125.

Utter, Jack; Gleason, William; McCool, Stephen F. User perceptions of river recreation allocation techniques. In: Lime, David W.; Field, Donald R., tech. coords. Some recent products of river recreation research; 1979 November; San Francisco, CA. General Technical Report NC-63. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981: 27-32.

Vaske, J. J. Contact-preference norms versus actual encounters: crowding among Brule River canoers. Paper presented at the annual meeting of the Rural Sociological Society; San Francisco, CA; 1978 August 21-23.

Vaske, J. J.; Donnelly, M. P.; Heberlein, T. A. Perceptions of crowding and resource quality by early and more recent visitors. Leisure Sciences. 3(4): 367-381; 1980.

Vaske, J. J.; Fedler, A. J.; Graefe, A. R. Determinants of hunting quality among Maryland waterfowl hunters. Paper presented at the fifth annual southeast recreation researchers conference; Asheville, NC; 1983.

Vaske, J. J.; Graefe, A. R.; Dempster, A. B. Social and environmental influences on perceived crowding. In: Proceedings, wilderness psychology group conference; [date and location of conference unknown]. Morgantown, WV: West Virginia University; 1982: 211-227.

Vaske, J. J.; Kuss, F. R.; Graefe, A. R. Recreation impacts and carrying capacity: a bibliography. College Park, MD: University of Maryland, Department of Recreation; 1984. 153 p.

Washburne, Randel F.; Cole, David N. Problems and practices in wilderness management: a survey of managers. Research Paper INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 56 p.

Watson, A. E. An application of behavioral decision theory to recreation site selection. Blacksburg, VA: Virginia Polytechnic Institute and State University; 1984. 221 p. Ph.D. dissertation.

Wellman, J. D.; Dawson, M. S.; Roggenbuck, J. W. Park managers' predictions of the motivations of visitors to two National Park Service areas. Journal of Leisure Research. 14(1): 1-15; 1982.

West, P. C. A nationwide test of the status group dynamics approach to outdoor recreation demand. Leisure Sciences. 5(1): 1-18; 1982a.

West, P. C. Effects of user behavior on the perception of crowding in backcountry forest recreation. Forest Science. 28(1): 95-105; 1982b.

West, Patrick C. Perceived crowding and attitudes toward limiting use in backcountry recreation areas. Leisure Sciences. 4(4): 419-425; 1981.

White, L., Jr. The historical roots of our ecologic crisis. Science. 155(3767): 1203-1207; 1967.

Williams, D. R.; Schreyer, R. Characterizing the person-environment interaction for recreation resource planning. In: Frazier, J. W.; Epstein, B. J., eds. Proceedings of applied geography conference; 1981 October 24-25; Tempe, AZ. Vol. IV. Tempe, AZ: Association of Applied Geographers; 1981: 262-271.

Williams, D. R.; Huffman, M. G.; Shafer, S. Avalanche hazards: improving the preparedness of cross-country skiers. In: Proceedings, Intermountain leisure research symposium; 1984 November 21; Logan, UT. Logan, UT: Utah State University; 1984: 53-55.

Wolfe, L. M., ed. John of the mountains: the unpublished journals of John Muir. Madison, WI: The University of Wisconsin Press; 1938. 459 p.

Womble, P.; Studebaker, S. Crowding in a National Park campground. Environment and Behavior. 13(5): 557-573; 1981.

Womble, Peter; Wolf, Wendy; Field, Donald. Hikers on the Chilkoot Trail: a descriptive report. Seattle, WA: University of Washington, College of Forest Resources, Cooperative Park Studies, Sociology Studies Program; 1978. 69 p.

Yankelovich, Skelly, and White, Inc. Research on public attitudes toward the use of wilderness lands. New York; 1978. 127 p.

Yoesting, D. R.; Burkhead, D. L. Significance of childhood recreation experience on adult leisure behavior: an exploratory analysis. Journal of Leisure Research. 5(1): 25-36; 1973.

Young, R. A.; Crandall, R. Wilderness use and self-actualization. Journal of Leisure Research. 16(2): 149-160; 1984.

Zuckerman, M.; Bone, R. N.; Neary, R.; Mangelsdorff, D.; Brustman, B. What is the sensation seeker? Personality trait and experience correlates of the sensation-seeking scales. Journal of Consulting and Clinical Psychology. 39: 308-321; 1972.

AUTHORS

George H. Stankey
Research Social Scientist
Intermountain Research Station
Forest Service
U.S. Department of Agriculture
Missoula, MT 59807

Richard Schreyer
Professor of Recreation Resources
Department of Forest Resources
Utah State University
Logan, UT 84321

WILDERNESS BENEFITS: A STATE-OF-KNOWLEDGE REVIEW

B. L. Driver, Roderick Nash, and Glenn Haas

ABSTRACT

Describes need for more objective information on wilderness benefits, especially as a base for formulating a sounder wilderness philosophy. Drawing on knowledge from the scientific and nonscientific literature on wilderness benefits, a taxonomy is presented that classifies benefits as personal, social, and intrinsic. Knowledge about each class and subclass within the taxonomy is considered. It is emphasized that most knowledge about benefits is based on introspective appraisals of benefits inferred from human preference studies. Closes with a discussion of which of the benefits are most, and which are least, central to development of a sounder wilderness philosophy.

INTRODUCTION

Since passage of the Wilderness Act (PL 88-577) in 1964, about 89 million acres (227 million hectares) have been included in the National Wilderness Preservation System in the United States. Even larger acreages of undesignated wilderness exist in the United States and in other countries. These designated and undesignated wildernesses are managed because of the benefits they provide. This paper describes what is known about those benefits. It says nothing about costs, a discussion also needed for a balanced understanding of wilderness values.

Why Understand Benefits?

Knowledge about its benefits can help managers and proponents of wilderness in several ways:

Enhance Rationality of Resource Allocation Decisions.—Public policymakers need to compare the benefits and costs of alternative uses of wilderness resources. These comparisons, which include but go beyond economic measures of benefits, have grown in importance as demands on public resources have increased and broadened. Among other things, information on wilderness benefits would help prevent making allocations for short-term gains that cause undesired long-term effects.

Help Promote Optimal Management.—Once basic public resources have been allocated to wilderness, information on benefits would improve the ability of the resource planners and managers to define clear management objectives and prescriptions and then establish more explicit standards and guidelines for meeting those objectives. The management objectives should be developed to maximize net wilderness benefits, including those accruing to the appreciative off-site users.

Identify Substitutes.—The information on benefits would also identify more clearly those benefits unique to wilderness, those that are not unique but highly preferred to be realized from wilderness, and those that can be obtained from alternative resources with no preference that they be realized from wilderness. Such information is needed to identify substitutes for wilderness uses.

Guide User Fees.—A basic tenet of public finance is that the beneficiaries should pay their fair share of the costs of providing a particular public good or service. Information on wilderness benefits would make it possible to better identify what type and proportion of those benefits accrue primarily to individuals (and to which types of individuals), to society at large, and to future generations. Thus, a better "multiple-part" pricing system could be designed under which different types of beneficiaries either pay user fees or are subsidized by public taxation.

Facilitate Additional Research.—Given that research is a building process, an understanding of the current state of knowledge about wilderness benefits would nurture additional hypotheses, research, and knowledge. In addition, the information on benefits could be used to cross-check the validity of techniques being used to measure wilderness values, such as the contingent-valuation method (Walsh and others 1984) for estimating users' willingness to pay for wilderness-related benefits.

Enhance Consumer and Voter Sovereignty.—Information on the benefits would facilitate more rational consumer and voter behavior with respect to wilderness use and protection.

Advance Professions.—Because the most fundamental feature of any profession is its body of knowledge, systematic information about wilderness benefits would advance the professions of those working on wilderness preservation, policymaking, planning, management, and valuation, and increase the personal pride of these professionals. Although subtle, such shifts could have profound impacts on promoting sounder wilderness policies and management.

Promote a Wilderness Philosophy.—An understanding of wilderness benefits is necessary to develop what we call a wilderness philosophy. This term signifies the underlying principles or values upon which the defense of wilderness can be built.

A sound and widely accepted philosophy has been notably absent in the American preservation movement, which can be characterized largely by a series of highly subjective defenses of particular places: "Save Hetch Hetchy," "Save the Redwoods," "Save Grand Canyon." If someone asked, "Why?", the reply was that it is the Grand Canyon, for Pete's sake! But still, why save it, why keep it wild? "Well," the preservationists traditionally retorted, "we like it wild." But their interrogator might persist, again, with the question, "Why?" The point is that wilderness appreciation has been a creed, a faith, something that was almost sullied by analysis and discussion, something you felt in your bones. But that is not good enough, especially when the existence of wilderness is challenged by deep-rooted materialism.

There is a need for a systematic articulation of wilderness benefits based not only on objective scientific research but also on historical fact and contemporary experience, including nonhuman values. This is what we mean by a philosophy of wilderness. It must lie behind the defense of particular wild places like the philosophy of human dignity and freedom lies behind the protest of racist policies. Philosophers have spent 24 centuries, since the Greek democracies, setting forth a philosophy of liberty. So, when Thomas Jefferson declared that all men were created equal, when Lincoln emancipated the slaves, or when contemporary Americans say that South Africa's apartheid is wrong, few ask why. But the value or benefit of wilderness is not nearly so well established. A major purpose of this paper is to summarize the best contemporary thinking on this subject in the hope that it will advance the articulation of a wilderness philosophy.

Definitions

Wilderness.—As Nash (1982) argues in "Wilderness and The American Mind," wilderness is a perceived reality—a state of mind. It is not just a particular collection of natural objects; it is a collection of feelings about those objects. Thus, wilderness has more to do with the contour lines in our heads than with those on maps; it exists, in other words, in the eye of the beholder. And there are a lot of beholders, which makes for a wide variety of definitions and management opinions. Thus, any attempt at a definition is arbitrary. For our purposes, wilderness will include, but not be limited to, land areas in the United States designated under the Wilderness Act. Included will be relatively large areas that are neither easily accessible nor frequently used by motorized vehicles, where opportunities exist for primitive types of recreation, and past and current human activities are not readily noticeable. The concepts of spaciousness and wildness are central, because that is what Americans have traditionally had in mind when they thought about wilderness.

Benefits.—Modern dictionaries generally define a benefit as a facilitator of an advantageous condition or state; for example, "something that guards, aids or promotes well-being"; "anything that enhances well-being"; "anything that is advantageous or for the good of a person or thing." According to these definitions, an aspirin is a benefit to someone with a headache, and a wilderness is a benefit to a grizzly bear. These things as facilitators can be called benefits even though the resulting advantageous conditions have not been specified. This definitional approach, therefore, does not disclose how wildernesses benefit humans and other organisms, which is the purpose of this paper. To serve that purpose, the dictionary definitions were extended to define a benefit as a specific advantageous condition, not the facilitator of such. Thus, the word "benefit" is used to denote a desirable change of state; it is a specific improved condition or state of an individual or a group of individuals, of a society, or even of nonhuman organisms.

We modify the dictionary definition to include also as a benefit the prevention of a worse state from happening. For example, if people are kept from harm, they have benefited or are in a better condition than if harmed, even if no improvement was made over the condition that existed before the danger emerged. Our definition focuses on advantageous consequences (for example, meeting held beliefs about stewardship responsibilities, increased appreciation of human-physical environmental interdependencies, medical advances from maintenance of species diversity) of such actions as preservation of wilderness, thinking about wilderness, and visiting wilderness. Our concept need not be anthropocentric; benefits to nonhuman organisms are included (Rolston 1982, 1985a, 1985b). It includes the economists' measures of the willingness of individuals to pay for the wilderness-related goods and services that provide the benefits on which those economic values are based.

Implicit in our definition of a benefit, as an improvement in a state, is the need to define why a change in a particular condition or state is beneficial or not. What constitutes an improvement, though, and who is to say? The judgments required to answer these questions are based on human beliefs and values, which vary from one context to another (Brown 1984); what is beneficial to one person at one time is not at another, and what is viewed as a benefit to one person or group might be viewed as a cost to another. Where possible, we have tried to define the benefits discussed. For example, the possibility of discovering a new medicine is one value of maintaining species diversity. However, it was frequently impossible to do more than list the benefit, or "define" it at face value. The reported spiritual benefits of wilderness are a good example.

The contextual difficulty of specifying wilderness benefits was also accompanied by what we will call "causative" and "inferential" problems. Frequently, benefits are viewed as synonymous with conditions that can cause the benefits to occur, and it is frequently easier to specify those conditions than the benefits. For example, opportunities for solitude, enjoyment of primitive types of outdoor recreation, and preservation of ecosystems and germ plasm are often called benefits of designated wilderness. These are not benefits as we have defined them but things that can lead to improved states, which might be replenished adaptive abilities, advancement of human health from discovery of a new drug, or increased mental satisfaction realized from knowing that good stewardship is being exercised.

The inferential problem arises from the need to differentiate subjectively defined desires for wilderness attributes from behavioral-change measures of wilderness benefits. We have no qualms with the notion that preferences guide behavior and that people generally behave reasonably and in their best interest. However, for the purposes of this paper we can interpret wilderness-related preferences only as perceived benefits, and then only if the preferences are for clearly defined improved states. For example, expressed preferences for opportunities to nurture family kinship, to exercise, or to escape a demanding job suggest that different benefits are perceived by the users. It cannot be assumed, though, that any behavioral-change measures made later would disclose greater family solidarity, improved physiological functioning, or behaviors reflecting increased productivity at work. This made our assignment difficult; although we would rather discuss wilderness-caused beneficial changes in behavior, virtually all studies from which inferences can be drawn about particular types of wilderness benefits have employed introspective reports that appraised the users' preferences for benefit-implying conditions. Very few studies analyzed changes in behavior that were categorized as beneficial by the researcher. Also, few of the economic studies that quantify willingnesses to pay to derive wilderness-related benefits have attempted to describe specific types of benefits being valued. Given that scores of studies have been conducted using subjective appraisals from which inferences to benefits can be made, much of what we report is drawn from that research.

HISTORY OF INQUIRY ABOUT WILDERNESS BENEFITS

Before the 1960's, the wilderness literature was dominated by "classical" writings (Gilligan 1955; Leopold 1921; Marshall 1930; Saylor 1956-57; Wagar 1940; Zahnizer 1955). These writings led to Congressional establishment of the National Wilderness Preservation System and prompted the initiation of wilderness research.

The emphasis of most early research was on the sociological and managerial aspects of wilderness. Those studies focused on management practices and user characteristics, such as densities, travel patterns, conflicts, and use rates (Brandborg 1963; Bultena and others 1961; Frissell and Duncan 1965; King 1965; LaPage 1963; Lucas 1963, 1964a, 1964b; Merriam 1964; Mueller and Gurin 1962; Stone and Taves 1958; Wagar 1963, 1964; Wenger 1964). Only a few studies considered benefits (Burch 1966; Etzkorn 1964; Outdoor Recreation Resources Review Commission 1962).

Toward the end of the 1960's, studies of user attitudes, motivation, and satisfaction began to provide some research-based information about values of wilderness to on-site users from which inferences to benefits could be made (Catton 1971; Cheek 1972; Hendee and others 1968; Knopf and others 1973; Lucas 1964c; Shafer and Mietz 1969; Stankey 1973). About this time too, or slightly earlier, the Outward Bound and other wildland challenge programs grew in the United States, with several studies of benefits to self-development accompanying this growth (Burton 1981). Studies too had been made of summer youth camps, but few focused on wilderness (Burch 1977).

Since 1970, additional studies have been made of the therapeutic/healing benefits of wildland settings for clinical types of programs for problems such as juvenile delinquency and drug abuse (Levitt 1982). Many more attitude and motivation studies involving wilderness users were conducted, as were additional sociological and economic studies (Driver and Brown 1983; Dwyer and others 1977; Kelly 1974; Knopf 1982; LaPage and Ragain 1974; Lime 1971; Nash 1977; Peterson 1974).

The Wilderness Act and the "environmental movement" of the late 1960's gave impetus to more ecological impact studies (Frissell 1973) and studies concerning wildlife (Kellert 1979; Ream 1980). In addition, 1977 amendments to the Clean Air Act focused some attention on the benefits of maintaining air visibility over Class I areas, which includes many designated as wilderness (Fox and others 1979; Johnson and Haspel 1983).

Over time, as demands grew and broadened for different uses of public lands, the concepts of scarcity and economic efficiency gained more prominence (Clawson and Knetsch 1966; Loomis and others 1984; McConnell 1983; Mills and others 1980). This trend stimulated a growing number of studies of the economic benefits of preservation actions (Bishop 1982; Randall and Stoll 1983; Walsh and others 1984).

In summary, little research has attempted to measure beneficial changes in behavior that can be attributed to wilderness preservation and use. However, much research has solicited users' opinions about wilderness values from which inferences to benefits can be made. Most of that research has occurred since 1970.

APPROACH

Delimitations

The lack of systematic research that focuses directly on wilderness benefits limits the state of knowledge in several ways that should be made explicit. Briefly, those delimitations are:

1. Some types of benefits have probably not yet been identified.
2. Almost all of the studies that have attempted to define particular types of benefits have used self-reports in questionnaires that measured users' subjective appraisals of benefits, or benefit-implying preferences, instead of measuring actual behavioral changes defined by the scientists as constituting particular types of benefits. It is impossible to state accurately the magnitude of any benefits inferred from this "perceived benefits" research that used introspective reports. The behavioral-based (for example, travel-cost methods) economic measures of recreation benefits do not specify particular types of benefits desired but instead value a particular recreation opportunity, site, or attribute of an opportunity.
3. Some of the research has not been sufficiently systematic; too frequently sample sizes were small and nonrandom, nonresponse bias was not accounted for, control groups were not used, longitudinal studies to trace responses over time were too few, and some scientists generalized too broadly from their data and even imposed their own values in their conclusions.
4. Very little study has been made of the benefits obtained by the off-site (vicarious or appreciative) users, whose numbers greatly exceed the on-site users.
5. Some of the research was not limited to wilderness-related phenomena but overlapped with nonwilderness uses in ways that were difficult to differentiate.

6. It was frequently impossible to determine if the benefits reported or inferred were uniquely attributable to wilderness.

Most of these delimitations can be explained as resulting from inadequate funds and the extreme complexity of the research. We will expand on No. 6 because it influenced our interpretation of knowledge about wilderness benefits.

As we see it, there are three categories of benefits provided by wilderness:

1. Benefits that can be obtained only from wilderness.
2. Benefits that can be obtained from both wilderness and nonwilderness, but for which wilderness is strongly preferred as the source.
3. Benefits that can be obtained from both wilderness and nonwilderness, but for which no strong preferences exist for wilderness as the source.

Three questions with respect to this listing and relevant to the purpose of this paper must be kept separate because the answers mean different things. First, can each class of benefits be attributed to wilderness? The answer is yes, if wilderness provides them, even though nonwilderness areas can provide types 2 and 3 and perhaps do so more cost effectively. Second, can each type of benefit be uniquely attributed to wilderness? No, only type 1 can. Third, should wilderness be maintained to provide each type of benefit? The answer is not up to us. If type 1 benefits are to be realized, they must be derived from wilderness. If enough people in a pluralistic republic desire type 2 benefits strongly enough, they will be provided by wilderness. Also, if these preferences are quite strong in the minds of those beneficiaries, the type 2 benefits might be as wilderness dependent as type 1. Because all three types of benefits can be attributed to wilderness, even though not uniquely so, we included each in our review of knowledge about wilderness benefits. We will consider the wilderness dependency of particular types of benefits in the last section of the paper.

Taxonomy of Benefits

The categories of benefits derived from a review of the scientific and nonscientific literature have been organized into a taxonomy (table 1) having three major categories: personal benefits, social benefits, and inherent/intrinsic benefits. Personal benefits are those that can be realized by individuals whether or not they can be aggregated across individuals. Social benefits are those realized by individuals collectively that accrue to society or subcultures of society. The third class, inherent or intrinsic benefits, are those benefits that accrue to plants and animals from wilderness preservation whether or not humans benefit currently or in the future from those benefits (Rolston 1982; Callicott 1985). The lengthy list of benefits in table 1 could imply a larger body of knowledge than exists. That risk accompanied our attempt to be comprehensive.

PERSONAL BENEFITS

Two types of users of wilderness and other natural areas are frequently identified in the literature, the on-site visitor and the off-site user. The latter either uses the resources from a distance vicariously or appreciatively according to a variety of held values, or realizes personal gains from the off-site use of wilderness-related commodities such as minerals, increased quantities or quality of water, range forage, and tourism income.

Both types of users receive personal benefits from wilderness resources. In fact, if personal benefits accrued only to on-site users, there would be little support for a wilderness preservation system simply because of the low percentage of the United States population that actively visits (or has visited) designated wilderness areas. This percentage has been estimated to range from 6 to 15 percent; whereas several surveys show 60 to 95 percent of the populations studied support the idea of wilderness preservation and have expressed willingness to be taxed for its support (Opinion Research Corporation 1977; Wallwork 1984; Young and Fry 1979; Young 1980). Nevertheless, most of the research on the personal benefits of wilderness has studied the on-site user, with little focusing on the vastly larger number of off-site users who are the predominant supporters of wilderness (especially designated wilderness).

Developmental Benefits

This category of personal benefits refers to any desirable changes in on-site wilderness users' self-concepts, self-actualization, or skill development and application.

Studies of Self-Concept Benefits From Sponsored Programs.—Two types of studies have addressed perceived changes in the self-concepts of wilderness users—research on participants in sponsored wildland challenge/adventure programs and research on general wilderness users. Each will be considered separately. Use of wilderness as "training grounds" by organized programs, such as Outward Bound and the National Outdoor Leadership School, has grown rapidly. Burton (1981) estimated that there are more than 300 such programs including those for juvenile delinquents, psychiatric patients, corporate managers, the military services, and educators.

The wildland challenge programs have received extensive study and several excellent review articles are available. Ewert (1983) focused on self-concept in his review of over 50 studies, and he critiqued them separately by types of programs, such as Outward Bound, survival training, and education programs utilizing outdoor adventure activities. Burton (1981), as a doctoral dissertation study at Rutgers, critically analyzed 72 studies of Outward Bound-type programs. Because these two reviewers agree closely in their summary interpretations, as we did too following a random review of several of the studies they analyzed, we will report the results of Burton's more comprehensive analysis.

Burton pointed out that 59 different evaluation instruments were used in the 72 studies to make a total of 115 measurements of 41 different outcome variables. These benefit-implying variables ranged from self-concept—through locus of control, anxiety, and self-actualization—to academic achievement and acceptance of others. Burton identified several methodological deficiencies with many of the studies (small sample sizes, failure to do follow-up studies, no or unmatched control groups, use of unstand-

Table 1.—Taxonomy of wilderness benefits

I. Personal benefits (accruing primarily to individuals and might or might not benefit society at large)
    A. Developmental (desired changes in self-concepts and skills)
        1. Self-concept
        2. Self-actualization
        3. Skill development
    B. Therapeutic/healing
        1. Clinical
        2. Nonclinical (stress mediation/coping)
    C. Physical health
    D. Self-sufficiency
    E. Social identity (development/maintenance of desired social relations with family and others)
    F. Educational
    G. Spiritual
    H. Esthetic/creativity
    I. Symbolic (benefits from options to realize that actions are being taken in support of preservation-related beliefs)
        1. Resource stewardship
        2. Anti-anthropocentricism/moralistic
        3. Option demands
        4. Other
    J. Other personal wilderness recreation-related benefits
    K. Commodity-related (benefits to individuals from goods produced from wilderness such as those related to water and to grazing by domestic animals)
    L. Nurturance

II. Social benefits (accruing across individuals to society collectively or to large segments of society)
    A. Aggregate personal benefits
    B. Spinoff benefits
    C. Historical cultural benefits
    D. Preservation-related benefits
        1. Representative ecosystems
        2. Species diversity
        3. Air visibility
        4. Unique landforms, including areas of outstanding scenic beauty
        5. Historic sites
        6. Educational values
        7. Scientific laboratory
        8. Stewardship (options for future generations)
    E. Quality of life
    F. Commodity uses (water, minerals, grazing, etc.)
    G. Economic benefits
        1. National economic development
        2. Local/regional economic development

III. Inherent/intrinsic (benefits to nonhuman organisms)

ardized tests, and no or insufficient statistical testing of score differences) and grouped the studies into All Studies (72) and Valid Studies (19). Burton then analyzed the two groups and reported the following percentage distribution of results:

Results	Distribution (All studies, 72)	Distribution (Valid studies, 19)
	Percent	*Percent*
Mostly positive	40	21
Some positive	36	47
No change	18	32
Negative	3	0

These findings indicate that, although more positive results were reported when the studies with "invalid" designs were included, about 70 percent of the studies with valid designs reported at least some beneficial change. Self-concept was the benefit-implying variable reported most frequently as having the most positive results in both categories of studies, in part because that variable was measured most frequently by the instruments employed. Burton stated that one of the most startling findings was that, across all studies reviewed, only three reported negative findings.

Burton's conclusions are that "it appears that Outward Bound-type programs do have positive effects. . . most substantial in the area of self-perception (self-concept, personality, locus of control and self-assertion)" even though few behavioral correlates were found. Burton proposes that it might take more time than the follow-up studies permitted for these behavioral changes to occur, as suggested by two studies that made follow-up measurements 5 years after the programs ended. Thus, beneficial behavior changes might have been greatest after a period of time not covered by most of the studies.

Studies of Self-Concept Benefits From General Wilderness Use.—Although no studies were found that

Table 2.—Mean scores[1] and their ranks (in parentheses) of responses to 16 wilderness recreation experience preference domains by users of eight designated wildernesses, four undesignated wildernesses, and three contrasting nonwilderness areas, with States in which located

Experience preference domains	Designated wildernesses							
	Weminuche (CO) (N = 313)	Maroon Bells(CO) (N = 268)	Flattops (CO) (N = 135)	Eagles Nest(CO) (N = 271)	Rawah (CO) (N = 212)	Linville Gorge(NC) (N = 249)	Shining Rock(NC) (N = 297)	Joyce Kilmer(NC) (N = 80)
1. Enjoy nature	1.5(1)	1.5(1)	1.5(1)	1.5(1)	1.7(1)	1.5(1)	1.6(1)	1.4(1)
2. Physical fitness	2.4(4)	2.0(2)	2.5(5)	2.3(2)	2.3(3)	2.1(2)	2.2(2)	1.8(2)
3. Reduce tensions	2.1(2)	2.3(4)	2.1(2)	2.4(3)	2.2(2)	2.3(3)	2.3(3)	2.1(3)
4. Escape noise/crowds	2.2(3)	2.2(3)	2.2(3)	2.4(3)	2.2(2)	2.3(3)	2.3(3)	2.2(4)
5. Outdoor learning	2.1(2)	2.4(5)	2.4(4)	2.5(4)	2.2(2)	2.3(3)	2.4(4)	2.2(4)
6. Sharing similar values	2.8(5)	2.9(6)	3.2(8)	2.8(4)	2.8(4)	2.7(4)	2.9(5)	2.7(6)
7. Independence	3.1(7)	2.9(6)	2.8(7)	3.3(7)	3.0(6)	3.0(7)	3.0(6)	3.0(8)
8. Family kinship	3.0(6)	3.0(7)	2.6(6)	3.2(6)	2.9(5)	3.4(9)	3.1(7)	3.0(8)
9. Introspection/spiritual	3.5(8)	3.1(8)	3.3(9)	3.7(8)	3.5(7)	2.8(5)	2.9(5)	2.6(5)
10. Considerate people	3.6(9)	3.4(9)	3.2(8)	3.8(9)	3.7(8)	3.0(7)	3.3(8)	2.8(7)
11. Achievement/stimulation	3.9(11)	3.1(8)	3.4(10)	4.0(11)	3.9(10)	2.9(6)	3.1(7)	3.0(8)
12. Physical rest	3.8(10)	4.3(10)	2.5(5)	3.9(10)	3.9(10)	3.2(8)	3.3(8)	3.4(9)
13. Teach/lead others	3.7(10)	4.3(10)	3.5(11)	3.9(10)	3.8(9)	3.6(10)	3.7(9)	3.9(10)
14. Risk taking	4.7(12)	4.8(12)	4.8(13)	4.6(12)	4.8(10)	4.1(11)	4.5(10)	4.6(12)
15. Risk reduction	4.8(13)	4.7(11)	4.7(12)	4.7(13)	4.8(11)	4.7(13)	4.7(11)	4.7(13)
16. Meet new people	5.6(14)	5.3(13)	5.5(14)	5.5(14)	5.8(12)	4.6(12)	4.5(10)	4.5(11)

Experience preference domains	Undesignated wildernesses				Nonwilderness areas		
	Indian Peaks(CO) (N = 101)	Vermont (VT) (N = 415)	Commanche (CO) (N = 424)	Shoshone (WY) (N = 165)	Little Sahara(UT) (N = 421)	Arkansas River(CO) (N = 442)	Lake Shelbyville(IL) (N = 1,567)
1. Enjoy nature	1.8(1)	2.5(2)	1.7(1)	1.9(1)	2.4(4)	1.7(1)	3.1(2)
2. Physical fitness	2.8(4)	2.7(4)	2.4(2)	2.2(3)	2.2(3)	2.3(4)	3.1(2)
3. Reduce tensions	1.9(2)	1.9(1)	2.4(2)	2.0(2)	2.7(5)	2.2(3)	3.3(4)
4. Escape noise/crowds	2.8(4)	2.8(5)	2.5(3)	2.0(2)	3.1(9)	2.1(2)	3.3(4)
5. Outdoor learning	2.4(3)	2.5(3)	2.5(3)	2.2(3)	2.9(8)	2.3(4)	3.8(6)
6. Sharing similar values	3.3(6)	3.0(7)	3.5(7)	3.1(7)	1.2(1)	2.3(4)	3.1(2)
7. Independence	3.2(5)	2.9(6)	3.2(4)	3.1(7)	2.7(6)	2.7(5)	3.7(5)
8. Family kinship	3.4(7)	3.6(9)	3.6(8)	2.5(4)	2.1(2)	2.1(2)	3.2(3)
9. Introspection/spiritual	3.3(6)	3.2(8)	3.4(6)	2.6(5)	3.5(12)	3.5(8)	4.1(8)
10. Considerate people	3.1(4)	—	3.3(5)	3.0(6)	—	—	4.8(10)
11. Achievement/stimulation	3.6(8)	3.3(9)	3.8(9)	3.1(8)	2.8(7)	3.1(6)	4.2(9)
12. Physical rest	3.1(4)	5.0(11)	3.4(6)	3.3(9)	3.2(10)	2.1(2)	3.0(1)
13. Teach/lead others	4.2(9)	—	4.1(10)	3.9(10)	3.6(13)	3.1(6)	5.2(11)
14. Risk taking	4.6(10)	3.2(8)	5.1(13)	2.2(3)	2.2(3)	2.2(3)	5.3(12)
15. Risk reduction	4.7(11)	—	4.5(11)	4.9(11)	3.3(11)	3.4(7)	—
16. Meet new people	5.1(12)	4.5(10)	4.9(12)	4.9(11)	3.5(12)	4.0(9)	4.0(7)

[1] Ratings were made on the following 9-point response format (with numerical codes used to compute means): Adds (to satisfaction): most strongly (1), strongly (2), moderately (3), a little (4), neither adds nor detracts (5); Detracts: a little (6), moderately (7), strongly (8), most strongly (9). Coefficients of variation were 20-50 percent of the means.

applied standardized instruments for measuring changes in self-perceptions of general wilderness users not participating in Outward Bound-type programs, quite a few studies have used various measures of the perceived importance that users assign to skill development, self-testing, and being challenged physically as reasons for participating in particular wilderness recreation activities. Table 2 shows the results of studies of users of eight designated wildernesses, four undesignated wildernesses (at the time of the studies in 1977 and 1978), and three contrasting nonwilderness areas. That table gives mean scores and rank orders of mean scores for 16 different recreation experience preference domains using psychometric instruments (Recreation Experience Preference scales) developed by Driver and his associates, notably Richard Knopf, Perry Brown, and Glenn Haas. (For a discussion of development and use of the scales, see Driver 1976; Driver and Cooksey 1980; Driver and Knopf 1976; and Haas and others 1980.)

The experience domains shown in table 2 tap more general recreation experience preferences than did the 38 more specific scales (shown in table 3) making up those domains. For each wilderness area studied, systematic samples of recreationists were asked after participation to rate how much each type of experience would either add to or detract from their level of satisfaction with their visit to a particular area for their chosen type of recreation activity. Ratings were made to the nine-point response format described in the footnote to table 2. Only a small amount of the data given in table 2 has been reported previously by Brown and Haas (1980); Haas and others (1980); and Roggenbuck (1980). For that reason those data are summarized in this state-of-knowledge paper, without statistical testing of differences between areas.

Table 2 shows that although pursuit of other benefit-implying psychological goals ranked higher in overall importance, scale items within domain 11 (achievement/stimulation), which tapped preferences related to self-concept ("development of skills and abilities" and "gaining a sense of self-confidence"), were rated as being a little to moderately important ($\bar{x}=3.0$) to the visitors to all the areas studied, including the nonwilderness areas. Other studies of wilderness users support these results (Ditton 1981; Peterson 1971; Schreyer and Nielsen 1978a). Thus, wilderness recreationists perceive that developing skills is a desired benefit of their wilderness recreation activities. Of course, the importance of these self-concept-related benefits varies from one type of user to another.

Self-Actualization.—Maslow (1969) conceived of self-actualized individuals as being those who operate at the peak of their "needs hierarchy," which is considered by many supporters of that idea as the ideal psychological state, where effective functioning is optimal. Drawing on this concept, Scott (1974, p. 236) hypothesized that "wilderness experiences are more likely to foster self-actualization and the occurrence of peak experiences than outdoor activity in more degraded environments." Young and Crandall (1984) tested this hypothesis in two studies. One (1984) showed small, but statistically significant ($P \leqslant 0.03$) differences (on Shostrom's [1974] Personality Orientation Inventory) in self-actualization between Illinois users of the Boundary Waters Canoe Area (BWCA) and nonusers of wilderness. There were no differences between those who used the BWCA frequently in 1976 and those who used it less frequently. Since these results were only for the period of 1976, Young and Crandall (1986) conducted a second and longitudinal study of BWCA users, with questionnaires administered in 1979 and 1984. They report, "Self-actualization scores were significantly higher in 1984 than in 1979. In comparing the more active users in the panel with the less active, self-actualization increased for both groups but significantly more for the active users." They conclude that the results "suggest that wilderness use may cause increases in self-actualization either directly or through moderating variables."

Skill Development.—In addition to development of improved self-concepts and enhanced abilities for self-actualization, the recreation experience preference studies, and other introspective studies, indicate that wildernesses are used for skill development and competence testing—the labels given two scales in domain 11 (achievement/stimulation) in table 3. Table 2 shows that the values

Table 3.—Recreation experience preference scales making up the recreation experience preference domains abbreviated in table 2

1. Enjoy nature
   - A. Scenery
   - B. General nature experience
2. Physical fitness[1]
3. Reduce tension
   - A. Tension release
   - B. Slow down mentally
   - C. Escape role overloads
   - D. Escape daily routine
4. Escape noise and crowds
   - A. Tranquility/solitude
   - B. Privacy
   - C. Escape crowds
   - D. Escape noise
5. Outdoor learning
   - A. General learning
   - B. Exploration
   - C. Learn geography of area
   - D. Learn about nature
6. Share similar values
   - A. Be with friends
   - B. Be with people having similar values
7. Independence
   - A. Independence
   - B. Autonomy
   - C. Being in control
8. Family kinship[1]
9. Introspection
   - A. Spiritual
   - B. Personal values
10. Be with considerate people[1]
11. Achievement/stimulation
    - A. Reinforcing self-confidence
    - B. Social recognition
    - C. Skill development
    - D. Competence testing
    - E. Seeking excitement
12. Physical rest[1]
13. Teach/lead others
    - A. Teaching/sharing skills
    - B. Leading others
14. Risk taking[1]
15. Risk reduction
    - A. Risk moderation
    - B. Risk prevention
16. Meet new people
    - A. Meet new people
    - B. Observe new people

[1] These domains have only one scale, with the same title as the domain.

tapped by that domain added moderately to the overall experience of most of the wilderness recreationists studied in the 12 locations shown. These overall mean scores disguise the fact that skill development and competence testing are frequently of even greater importance to particular subgroups or market segments (Manfredo and others 1978).

Therapeutic/Healing Benefits

Clinical Studies.—Just as for the self-concept benefits, programs are sponsored to capture a variety of therapeutic benefits attributed to wilderness. Levitt (1982), in her overview of studies of "wilderness therapy," states that more than 100 such studies have been done to appraise the value of wilderness-related clinical programs in improving the effective performance of delinquents; in- and out-patients of psychiatric institutions, including emotionally disturbed children; drug abusers; and others having clinical problems. Levitt critically questions the research designs of the studies and apparently writes them all off as invalid. The design problems detected, in addition to some of the methodological ones raised for evaluation of Outward Bound-type programs, were lack of sufficient control of various extraneous and intervening variables and imprecise definition of wilderness given that many of the programs were not operated in wilderness settings.

Although we share the concern that tighter research designs are needed, our interpretation of the literature is a little more lenient and conforms more to the conclusions of the reviews by Barcus and Bergenson (1982) and by Gibson (1979). Specifically, the better designed studies show evidence of some therapeutic gains; patterns for recidivism across the studies are not clear, so no generalizations can be made other than that suggestions of reduced recidivism in different types of problematic behaviors appear frequently but not consistently. The most troublesome questions are whether these beneficial gains can be attributed to features of the wilderness or natural settings, to removal from institutional settings, or to the attention received from the counselors during the program.

Nonclinical Studies.—Many studies using self-reports indicate that the general public uses wilderness to gain therapeutic benefits. In more than a hundred studies in which the Recreation Experience Preference scales have been applied, including dozens of wild river studies by Lime and his associates (Knopf and Lime 1984), the themes of re-creation (coping temporarily with a variety of mental and physical stresses, physical rest, change of scene, etc.) always rank in the top, most highly valued reasons for engaging in all activities studied. Thus, various dimensions of stress reduction are pervasive motivators for most leisure pursuits (Driver 1976; Driver and Knopf 1976; Mandell and Marans 1972). Specific to wilderness, table 2 shows that the general experience preference domains 3 (reduce tensions) and 4 (escape noise and crowds) ranked second and fourth in importance (among the 16 preference domains measured) for users of all but one (Vermont) of the 12 designated and de facto wildernesses studied. Experience preference research suggests also that specific scales related to seeking tranquility, isolation, privacy, and solitude (with all its subdimensions [Hammitt 1982a, 1982b]) are the most dependent on wilderness settings, and in some instances rather uniquely so, especially for particular subgroups of users. Furthermore, Stephen and Rachel Kaplan have done creative and integrative work in defining the descriptive and predictive dimensions of what they call "restorative environments." Those dimensions include attributes such as tranquility, peace and silence, wholeness, and oneness that call primarily on involuntary rather than voluntary attention (Kaplan 1978; Kaplan and Talbot 1983).

Ulrich (1981) has reported studies showing that subjects, when viewing slides of natural (not necessarily wilderness) scenes, displayed higher physical manifestations (alpha brain wave and heart rate) of wakeful relaxation than when viewing slides of urban scenes. His 1984 article suggests that hospital patients recovering from surgery benefited more from window views of natural scenes than views of other scenes. He also has recently completed another study that used other physiological correlates of recovery from anxiety and stress (muscle tension, skin conductance, and pulse transit time, a noninvasive measure that correlates with blood pressure). It showed faster recovery by subjects viewing videotapes of natural scenes than those viewing urban scenes (Ulrich 1986). To be sure, conclusions from studies of natural versus urban areas should not carelessly be extended to wilderness, but neither should the studies go unnoticed.

Physical Health Benefits

Travel to and within wilderness areas generally requires some physical activity, and it is frequently extended and aerobic. Therefore, the physical health benefits attributed to physical activity (Buccola and Stone 1975) are at least partially contributed to by wilderness-related exercise even though such exercise could be attained in other than wilderness environments. Interestingly on that note though, desire to "exercise and for physical fitness" (domain 2) was generally rated second to fourth in importance among the 16 molar experience preference domains shown in table 2 for users of the 12 wildernesses studied. Many other studies of "motivations" of active wilderness recreationists also rank exercise and/or physical challenge as highly valued benefit-implying preferences (Brown 1981; Lee and others 1982; Schelhas 1979). Thus, although physical exercise can be obtained in nonwilderness environments, it is strongly preferred by—as well as required of—on-site users of wilderness areas. It should be noted that the recently incorporated Wilderness Medical Society (with a membership of 500 physicians across the United States) is directing its research toward the human physiological effects of recreating in wilderness-type areas.

Self-Sufficiency Benefits

Robert Marshall (1930) was a strong proponent of the argument that wilderness provides "opportunity for self-sufficiency." Thoreau, even earlier, touched on this theme in his awareness of the value of occasional reversions to the primitive, and he tested this during his stay at Walden Pond. More recently, authors such as Wagar (1940) and McAvoy and Dustin (1981) have echoed that theme. Strong inferences about these types of benefits can be drawn too from the many studies (for example, Rossman and Ulehla 1977) that show self-testing, seeking adventure, and challenge are important psychological attributes of wilderness outings. That importance is especially great for particular "market segments" such as those participating in the sponsored Outward Bound-type and challenge-related therapeutic programs and participants in high skill-demanding activities in wilderness, like technical mountain climbing and orienteering (Manfredo and others 1983). In a recently completed study by B. L. Driver, Glenn E. Haas, and Thomas Greene to test some basic tenets of the Recreation Opportunity Spectrum (ROS) System (Driver and others, in press) new recreation experience preference scales were applied to determine how important "testing the need to rely on one's outdoor skills" and to be "self-reliant in the use of woods skills" were as reasons for hiking, fishing, and camping in Rural to Primitive ROS classes. Those two experience preferences proved to differentiate predictively the visitors to the different settings and were always most highly valued in ROS classes toward the primitive end of the spectrum.

Social Identity Benefits

Contrary to intuition, but consistent with sociological theory, wilderness recreationists aspire to gain many benefits that stem from social interaction. Probably the most pervasive and one of greatest magnitude relates to family cohesiveness and solidarity. Others include strengthening social bonds with small groups of significant others, sharing skills with others, and gaining social recognition or status from demonstration of skills to others and later sharing tales or photographs of enviable experiences. Wilderness use by organizations, including the Outward Bound-type and therapeutic programs, and wilderness tours such as those sponsored by the American Forestry Association can also logically be assumed to provide socially defined benefits to the individuals participating.

Dozens of studies of recreation experience preferences and motivations and of the sociology of wilderness recreationists show that these socially related perceived benefits are quite widespread and of considerable value (Brown 1981; Cheek 1981; Heberlein 1977; Kelly 1981; Lee 1977; Schreyer and Roggenbuck 1978b; Stankey 1972). See also the mean ranks of experience preference domains 6 (share similar values) and 8 (family kinship) in table 2. Lucas (1980) showed behavioral correlates to these types of results in that, with one exception, 51-63 percent of the user groups sampled in the nine wildernesses he studied were either in family groups (which represented by far the larger percentage of any group) or groups made up of family and friends. Also, roughly 40 percent of the parties included children under 16 years old, and less than 6 percent were visiting any of the nine wildernesses alone.

Perhaps more abstract, but still of considerable personal and social significance, are the benefits of leisure (including wilderness recreation) in nurturing various dimensions of social cohesion. Establishment of trust, open communication, and sharing of ideals and problems are enhanced under conditions where formality and role barriers are reduced (Cheek 1981). It is during these times that persons gain and share information about some of their most important decisions.

Educational Benefits

Numerous studies of on-site wilderness users document that exploring and learning about nature—even getting a feel for the geography of a particular piece of land—are important to practically all wilderness recreationists. Those desires ranked second to fourth in importance in all but one (Maroon Bells-Snowmass) wilderness in table 2 (see experience preference domain 5). Confirming results can be found in the dozens of river recreation studies by Lime and his associates and by other researchers (Ditton 1981; Lee and others 1982; Peterson 1971).

It seems reasonable to propose that off-site users realize sizable educational benefits from the time they devote to reading wilderness literature (coffee-table-size illustrated atlases, National Geographic magazines) and to watching TV specials devoted to wildlands and animals, and from knowledge obtained from their memberships in preservation-related organizations. This learning could prompt other benefits, such as greater behavioral commitment to conservation and preservation and support of a prudent approach to resource development. Of course, others with developmental interests could view these values as constraining their realization of benefits defined in a different context.

Spiritual Benefits

People today acknowledge the wisdom of the many people, including the American Indians and other aboriginals, who regarded places, not just buildings with steeples, as sacred. Wilderness appreciation in Europe and America really began with the revolutionary idea that the least-modified environments were the purest expressions of God's power and glory. From the transcendentalism of Henry David Thoreau and Ralph Waldo Emerson to the "cathedral mountains" of John Denver, wilderness acquires importance as a setting for answering the deepest questions of human existence, for celebrating the creative power behind life and things, and for understanding the unity of them all. These are religious functions (Graber 1976), which suggests that the American wilderness could be defended by the Constitutional guarantee of freedom for citizens to worship as they choose. Even if those who look upon wilderness as a church are a minority, protection of a minority's right to worship in its own way is a basic part of the American democratic creed, despite the difficult task of determining the type and size of wildernesses needed to meet these rights.

Some research findings do show that development and expression of spiritual values are important dimensions of the wilderness experience. For example, in table 2, domain 9 (introspection/spiritual) ranks of a little to moderate importance and tends to be valued slightly higher in most of the wilderness areas than the nonwilderness areas. Rossman and Ulehla (1977) too found that their sample of University of Colorado students reported very important "psychological reward values" (potentially available from wildernesses) from having the "chance for spiritually uplifting experiences."

Esthetic/Creativity Benefits

In our concluding section, we will suggest that it might be counterproductive to base a wilderness philosophy on values, such as scenery, that can be realized in substitute areas. We believe the broader concept of esthetics—which perhaps should include spiritual development—is a justifiable base. Nevertheless, we cannot deny that scenic enjoyment in and of itself is an important motivator of wilderness use. Despite this conflict, our rationale is based on the belief that beyond scenery there is a particular kind of beauty dependent on wilderness settings. Beginning in the 17th and 18th centuries, romantics called it the sublime. It stemmed not from near-pastoral environments but from vast, disordered, powerful, awesome places that reflected the frailty of human beings. The idea of sublimity, for instance, transformed human views of mountains from warts and pimples disfiguring the earth to majestic, beautiful features. People began to climb them for pleasure. Painters like Albert Bierstadt and Thomas Moran and photographers like Ansel Adams publicized the new esthetics. The current popularity of wilderness art dramatizes the fact that contemporary artists and appreciators of art still find unique esthetic value and opportunities for creative expression in wilderness settings.

There is considerable documentation of the perceived esthetic value of wilderness. In a word-association study by Heberlein (1982), the word "beauty" ranked fifth (of the 36 reported) in frequency of being free-associated with the word wilderness. One of the first studies of wilderness experience preferences reported that esthetics were rated of the highest importance to the visitors surveyed in the Mount Marcy Wilderness in the Adirondacks (Shafer and Mietz 1969). Table 2 shows that the experience domain "enjoy nature" ranked first in importance across all the designated wildernesses and all but one (Vermont) of the de facto wildernesses. The data are not provided in table 2, but the scale "scenery" (see table 3) received slightly higher mean scores than the other scale constituting the "enjoy nature" domain. Although the scale "creativity" was not included in most of the studies shown in table 2, it was included in studies of the Flattops, Rawah, Linville Gorge, Shining Rock, and Joyce Kilmer/Slickrock Wildernesses and received mean scores indicating moderate importance.

This pattern of values for esthetics and scenery is confirmed by Brown (1981) in his summary matrix of highly valued experiences derived from outdoor recreation, including recreation in wilderness areas. Finally, in response to an open-ended question asking visitors why they chose to visit a roadless wilderness instead of some other type of area, "scenic beauty" ranked (by frequency of being mentioned) as second in five, third in two, and fourth in two of the nine areas studied by Lucas (1980).

Despite the high ratings of esthetic/scenic appreciation in all wilderness studies measuring that preference, Anderson (1981) raises a caution. She found that student subjects at the University of Arizona rated slides labeled "wilderness area" and "natural park" higher than those designated "commercial timber stand," "leased grazing range," "national forest," and "recreation area" despite the fact that six randomly selected subsets of slides of the same area (not of six different areas) were shown to solicit each of the valuations; the slides were all of the same area, and only the labels assigned to the six randomly selected subsets of slides differed. The slides of the area were selected to exclude much modification by humans because of the inclusion of the wilderness area category in the experiment. The caution is that scenic qualities are a part of people's image of wilderness whether or not such qualities are in fact greater in a particular wilderness than elsewhere; just the label "wilderness" elicited those images in the Anderson study.

Symbolic Benefits

This category denotes benefits that people realize just from knowing that wild things are being preserved consistent with their preference. As Wohlwill (1983, p. 86) puts it, "Nature represents a construct, that is a product of our intellect and imagination, defining the characteristics, as well as the power that we attribute to it." Thus, we can and do attribute values to preservation consistent with our values and beliefs, and we must benefit from any consonant perceptions. Again, the context is important; others could perceive loss of benefits if their values favor development.

Specific dimensions of these symbolic values include the benefits individuals derive just from knowing that society collectively is being a good steward through conservation and preservation actions. Included are the existence, option, and bequest demands studied by economists (Walsh and others 1984). Haas and others (1983) found that two groups of Colorado residents, who had and had not visited wildernesses, both believed the fourth and fifth most important reasons (out of 13) for preserving wilderness were "knowing that future generations will have wilderness" and "knowing that in the future you have the option to go there." Also at the personal, as well as the social, level are ethical/moral sentiments (Rolston 1981) about human responsibilities to respect nonhuman organisms (discussed in greater length in the section on Inherent/Intrinsic Benefits).

It is quite difficult to appraise these symbolic benefits. Kellert (1983) reports from his national survey that a moralistic attitude toward animals, especially wildlife, was the second most prevalent attitude toward animals, including wildlife. He defined that attitude as "primary concern for the right and wrong treatment of animals." Another attitude with ethical overtones, ecologistic (concern about the environment as a system), was pervasive but of lower overall rank. More (1977) examined the index of "Children's Books in Print, 1972" to determine the number of titles that included the words "animal" or "wildlife" or mentioned a particular type of animal. Expressing frustration that he had to pass up "Little Red Riding Hood" and "Bambi," he found that in 1972, of the 40,250 children's books in print, 5,473 (13.6 percent) had one or more animals mentioned in the title. He discusses some of the possible effects of this imagery or symbolism, and suggests the impacts are considerable on the attitudes and behavior of the children and their maturation. Some animals commonly associated with wilderness are important for this symbolism. Nash (1982) established that the word "wilderness" has always had symbolic value.

Other Personal Wilderness Recreation-Related Benefits

In general, the most salient benefits suggested by many preference studies of wilderness recreationists have been considered in the categories of personal benefits discussed above. Those studies reveal, however, that other less salient benefit-implying conditions are also strongly desired by most users; practically all of the experience preferences shown in table 2 were reported to add at least a little ($\bar{x}=4.0$) to satisfaction by all visitors studied. For example, that table indicates other benefits not emphasized in the taxonomy offered in table 1. Included are autonomy and independence, pitting one's wits against animals hunted or fished, and being stimulated. Other personal benefits suggested by the nonscientific literature include obtaining from wilderness a better appreciation of one's historic roots and a sense of humility.

In addition, the overall most salient perceived benefits inferred from table 2 mask the fact that there are variances around these mean values; other preferences are most salient for particular subgroups. For example, Haas and others (1980) and Manfredo and others (1983) found that one market segment of wilderness users scored much higher on preferences for risk taking than the other segments. Thus, although common overall patterns in benefit-implying, wilderness-related preferences can be documented, there are also particular preferences for different segments of wilderness visitors.

Commodity-Related Benefits

In addition to the noncommodity-related personal benefits, there are benefits to individuals and to society from the commodities and marketed services (water, for example) provided by wilderness areas. Timber used to build houses is harvested from many undesignated wildernesses, and goods and services ultimately provided from other resources (minerals, forage) provide off-site benefits too. The benefits of most importance in this category are probably those that accrue from protection of watersheds. Haas and others (1983) compared two groups of Colorado residents, one that had and another that had not visited wildernesses; both valued the protection of water resources in wilderness the highest among the 13 wilderness-value items listed.

Nurturance Benefits

This last category of personal benefits is novel to the literature and a little more abstract and speculative. It denotes the benefits realized by altruistic people who nurture options for other people to benefit currently from wildernesses. The benefits are to the nurturers, who feel good about themselves for helping provide the opportunities for others currently. Nurturance benefits differ from the economists' idea of bequest values, a related concept in which the implied altruism is directed toward future users.

Our belief is that, just as good teachers nurture opportunities for their students to have rich learning experiences and just as good parents nurture rich living/growing experiences for their children, citizens of a good society nurture the arts, support fluoridation of public drinking water (even if the supporters wear dentures), promote opportunities for leisure enjoyment, and favor sensitivity to nonhuman organisms and future people. We would have no wilderness preservation system if these types of values did not exist. Although these benefits would be difficult to quantify, in aggregate they are probably significant.

Summary on Personal Benefits

To summarize, many different types of personal benefits are found from wilderness preservation and use. However, it could be hazardous to generalize all of the personal benefits of active users of wilderness to all potential users. As Peterson (1971) suggested, wilderness users might not be a random subset of the population. Kaplan (1974) found that participants in the Outdoor Challenge program she studied scored higher on the pretest of self-esteem than the control group of nonparticipants. Young and Crandall (1984) found a little support ($p=0.3$) that potential users of the BWCA scored higher on self-actualization than the other nonusers who were not classified as potential users. There could be some individual differences that predict realization of particular types of benefits. This does not mean that users do not benefit, only that they might benefit differentially from the same type of use. Evidence for this is available from several wilderness market segmentation studies (Brown and Haas 1980; Haas and others 1980; Manfredo and others 1983). These results serve again to show the diversity of benefits probably obtained by users having different preferences.

Lastly, table 2 provides data on general wilderness experience preferences from which inferences to particular types of benefits can be drawn. Those data show that recreational users of wilderness share many dimensions of their preferences with outdoor recreationists using nonwilderness areas. Those data, in addition, show the most consistent pattern in mean rank scores for users of designated wilderness, followed by users of de facto wilderness. This suggests there might be greater predictability of experience preferences for wilderness users than for users of nonwilderness areas. One might infer that specific types of experiences, and perhaps benefits, might be more wilderness dependent than others, but this hypothesis needs further testing.

SOCIAL BENEFITS

Eight classes of social benefits were listed in the taxonomy of wilderness benefits presented in table 1. Some of the categories, especially the "spinoff benefits," largely defy scientific appraisal because of the problem of establishing research controls that would clearly establish cause-effect relationships that link wilderness preservation and use with benefits, while excluding other possible causes of the benefits. Also, some of the benefits probably occur with a time lag that confounds systematic research, as does the difficulty of establishing control groups. Therefore, although some of the proposed types of social benefits of wilderness might well exist and be nurtured through many channels, little research has been done—or likely will be done—to document this. For that reason, some of this discussion must be speculative.

Aggregate Personal Benefits

This category comprises those personal benefits that, when aggregated, also contribute to collective social welfare. Any health-related or ecological learning ("space-ship earth") benefits are examples.

Although there is no way of measuring the cumulative personal benefits of wilderness that are realized by all users, this sum probably contributes substantially to the quality of American life considering the diversity of personal benefits considered and the number of on- and off-site users, especially the latter. As just one example, the therapeutic and stress-mediating benefits, when aggregated across all beneficiaries, probably represent a sizable total.

Spinoff Benefits

This class of benefits has been labeled "merit good" and "spinoff" benefits in the public finance and welfare economics literature. The benefits are also called external economies, meaning that meritorious or good things are spun off to nonconsumers (nonusers) from the production or consumption of a particular good or service. Public education has been the classic example; if citizens are educated, they supposedly are more productive people, less prone to antisocial behavior, and can participate more intelligently in a democracy (voting, volunteer work, etc.). Thus, society in general benefits as a side effect of citizens being educated.

One subclass of possible external economies from wilderness preservation and use denotes a type of personal benefit that creates a similar but not identical benefit to society. If people restore adaptive and work energies while using a recreation (Grubb 1975) or wilderness area and as a consequence show increases in the subsequent quality or quantity of their work, those individuals benefit from increased pride in work, more job security, and perhaps advancement in position and salary. The spinoff benefits to society are increased productivity, improved comparative advantage, and increased national economic wealth. The personal and social benefits differ some, but both relate to increased productivity and wealth. The second class of spinoff benefit denotes that a type of social benefit is created different than the benefit realized by the users from whom the spinoff originated. Both on- and off-site users, for example, might obtain increased national pride from knowing that their country thinks as a matter of principle it is important to preserve part of its natural bounty and cultural heritage. This enhanced pride could spin off into greater social cohesiveness or even greater participation in social institutions such as voting in public elections. Or, individuals might support and benefit personally from wilderness preservation solely because they wish to maintain options to use the areas in the future, and that support helps create the opportunity to develop later from a preserved species a drug that promotes human health collectively.

One can reasonably speculate that there are beneficial social spinoffs of wilderness use and preservation that take the form of increased work productivity, reduced public subsidy for mental and physical health, advantageous consequences of any stress mediation-related personal benefits, and better social bondings. The problem is there are diverse factors (physical features of home, neighborhood, and work environments, marital and family status, cognitive style, education, age, personality, other leisure behaviors, patterns of social interactions of the users, etc.) that can separately and interactively (with wilderness use) cause desirable changes in society. There is also the difficulty of defining what these social spinoff benefits are (such as collective improved mental health or a higher overall quality of life). For these reasons, it is impossible to determine how many spinoff benefits there are from wilderness. We will continue to rely on the political-democratic process, rather than scientific inquiry, to register public sentiments about these relatively intangible benefits.

Historical Cultural Benefits

The United States achieved political independence before it attained cultural independence because of provincialism —Americans felt inferior to the Old World. There was little distinctive or distinguished about American culture or character. The most hostile America-baiters even alleged that the new heterogeneous nation in the backwoods lacked a culture—that it was not a bona fide nation at all (Nash 1982). In response, Americans searched for something that was different and impressive about their country. Wilderness came to the rescue. The New World might not have the history and tradition of Europe, but it was abundantly endowed with wilderness. Moreover, since wild environments possessed spiritual and esthetic uniqueness compared to modified ones, it followed that Americans could use them for cultural purposes. This train of thought transformed wilderness from an embarrassing liability to a coveted asset. Americans did not have to be cultural copycats anymore. Europe might have its Roman ruins and medieval cathedrals, its Leonardos and Shakespeares, but America had Niagara Falls, buffalo, Indians, and the Rocky Mountains. Sure the Alps were mountains, but highly developed ones, saturated with civilization. Its vast and undeveloped wildlands and resources gave the new nation the substance for national pride.

In time, of course, American artists and writers realized the promise of the wildness of the New World. James Fenimore Cooper and Thomas Cole led the way in the 1820's, producing the first critically celebrated and distinctively American novels and paintings, and it was their use of wilderness that set them apart (Nash 1982). Subsequent Western painters—one thinks of George Catlin, Charles M. Russell—and contemporary artists carried on the tradition of using nature as a basis of nationalism.

Wilderness has also made substantial contributions to national character. In 1936, Gertrude Stein, long a resident of Europe, put her finger on an important fact. "In America," she wrote, "there are more places where nobody is than where anybody is. That is what makes

America what it is." Stein was referring to wilderness as a shaping force on America and Americans. The frontier, as the historian Frederick Jackson Turner (1920) pointed out, is the quintessential American historical environment, the shared situation that shaped the national character. Writing in 1893 only 3 years after the census pronounced the American frontier dead, Turner implied that wilderness was the best means of sustaining essential American traits like the love of freedom and democracy. He sensed that eliminating wilderness would be comparable to tearing the pages out of a library book.

The love of liberty is one of the hallmarks of American national character, and there has been a deep historical relationship between wilderness and freedom. Wallace Stegner has a beautiful way of expressing it. In 1960, he called wilderness and the idea of wilderness "part of the geography of hope" (Nash 1976, p. 192). It was an environment that permitted people to be different, to experiment, to resist, to rebel. The Puritans, fleeing the repressive culture of a nation that did not permit them religious freedom, began the tradition in the 17th century. The Mormons continued it in the 19th century when they migrated to the wilderness of Utah. Edward Abbey (1968, p. 149) still sees "political reasons" for preserving wilderness, as refuges from authoritarian and totalitarian systems of government. Freedom fighters traditionally take to the wilds—as long as there are wilds available. It was no accident that in his book "1984" George Orwell (1949) made one of Big Brother's first acts the elimination of wilderness.

The notion of freedom as a benefit of wilderness is supported too by table 2, which shows that "independence" (domain 7) was rated of moderate and slightly higher importance in the 12 wildernesses studied.

Preservation-Related Benefits

It is almost tautological to say that one of the consequences of wilderness management is to preserve wilderness resources. The difficult question is, What are the benefits from such preservations? Again, several subcategories of benefits appear to exist.

Representative Ecosystems.—A major reason for preserving wilderness is to protect and maintain representative ecosystems in different regions of the country. At face value, such efforts seem meritorious because almost all the ecology texts and articles reviewed proceeded under the assumption that preservation of representative ecosystems in their natural states is a good thing. Although articles have described wilderness ecosystems (Franklin 1978), provided general information about the benefits of ecosystem preservation (Westman 1977), or offered criteria for selecting areas, few have offered much help directly in appraising what the benefits are. One exception was the selection criteria offered by Margules and Usher (1984), which included several (amenity value, educational value, and scientific value) from which inferences to benefits could be made. Lucas (1984) was one of the few authors to discuss explicitly the benefits of conserved and preserved areas in the proceedings of the Bali World Congress on National Parks, even though the title of those proceedings was "The Role of Protected Areas in Sustaining Society."

Some authors have argued that ecosystem preservation is desirable because such actions will lead to increased stability and greater species diversity. Others suggest that, while diversity and stability are not always correlated, "they have had evolutionary relationships that run parallel [and that]. . .high environmental stability leads to high community stability, which, in turn permits, though is not determined by, high diversity of species" (Myers 1979, p. 49). Dasmann (1978) is more specific and points out failures of past authors to define terms adequately. He defines stability in terms of constancy and persistence, not absence of change. He then considers relationships between these two characteristics and resiliency and species diversity to point out the complexity of these interactions by his statement, "There is no clear relationship between diversity and stability or diversity and resilience" (p. 20). His message, which we find useful, is that "instead of one simple relationship there are many. . . to be investigated" (p. 20) from the relatively unstable and less resilient tropical rain forests to the *Spartina* marshes that are highly stable and resilient.

The inability to generalize from ecosystem to ecosystem and statements that things are complex and the consequences of disturbances unknown are frustrating to the nonecologist interested in beneficial functions. Still, this uncertainty and the potential for irreversibility are reasons for preserving representative ecosystems at least until more knowledge is obtained. Bishop (1978) has suggested that the economic costs of such preservation will be modest.

The foremost benefits of preserving representative ecosystems appear to be those of acting prudently in the face of uncertainty, which comes down to risk aversion—of preventing unknown and unwanted costs from being disclosed in the future. These are equivalent to the benefits realized by individuals who prudently undertake health-maintenance activities under a probabilistic stance; they feel better about it and might benefit in the future.

Species Diversity.—More definitive arguments have been made in the literature about the benefits of maintaining species diversity than about ecosystem preservation, even though the two are largely inseparable. But again many authors write as if the reader already understands why the preservation of species diversity (or of germ plasm) is good. Sparrowe and Wight (1975) offer a highly detailed list of biological characteristics and weights for use in setting priorities for the endangered species program. Although it was not their purpose to discuss benefits, no criteria were (and probably could not be) offered regarding the probable benefits of preserving the different species to which the system was applied. Similarly, Stone (1965) reported that we do not have clear objectives for preserving vegetation in parks and wilderness. Walsh (1981) reports that "germ plasm resources are losing ground," but he does not discuss why that is a problem.

Like preservation of representative ecosystems, some benefits of species preservation can be attributed directly to such preservation action while other benefits might or might not be directly related. We will consider here those that are directly related.

Several surveys studying the meanings and values of wildlife—although not necessarily wilderness-dependent wildlife—give some feel for the perceived benefits of species preservation. Kellert (1980), in a national sample (3,107 respondents), developed and applied a 10-dimensional typology of attitudes toward wildlife. He has reported on these and other measures made in several publications. The attitudes and Kellert's (1980, p. 34-35) definition of each are shown in table 4, along with his (p. 37) estimate of the percentages of the sample population strongly oriented toward each attitude and the common behavioral expressions and benefits related to each. The table indicates several perceived benefits related to maintaining diversity, especially attitudes 2, 4, 5, and 7.

Shaw's (1979) study of antihunting sentiments solicited ratings from three groups of Michigan respondents of reasons why wildlife were important to them. The groups were Michigan deer hunters, Audubon Society members, and supporters for the Fund for Animals. The respondents rated these reasons from most to least important: (1) wildlife is a part of the ecological balance upon which we are all dependent; (2) people enjoy viewing wildlife; (3) people enjoy just knowing that wildlife exists; (4) wildlife is of scientific value; (5) wildlife plays an important part in our cultural heritage (songs, legend, etc.); (6) wildlife provides hunting recreation; (7) wildlife helps the economy by attracting tourism; (8) wildlife are a source of food and furs; (9) and wildlife have souls like humans. Again, benefits are either explicitly stated or implied by many of these reasons. One can infer that maintenance of species diversity would be viewed as fundamental to the highest rated sentiment, maintaining ecological balance.

Interestingly, the three diverse and frequently conflicting groups studied differed little in the mean importance

Table 4.—Kellert's (1980) typology of attitudes toward wildlife and inferences to possible benefits

Attitude typology	Estimated percentage of American population strongly oriented toward the attitude[1]	Common behavioral expressions	Most related values/benefits
1. **Naturalistic:** Primary interest and affection for wildlife and the outdoors.	10	Outdoor wildlife-related recreation—backcountry use, nature birding, and nature hunting	Outdoor recreation
2. **Ecologistic:** Primary concern for the environment as a system, for interrelationships between wildlife species and natural habitats.	7	Conservation support, activism and membership, ecological study	Ecological
3. **Humanistic:** Primary interest in and strong affection for individual animals, principally pets. Regarding wildlife, focus is on large attractive animals with strong anthropomorphic association.	35	Pets, wildlife tourism, casual zoo visitation	Companionship, affection
4. **Moralistic:** Primary concern for the right and wrong treatment of animals, with strong opposition to exploitation or cruelty toward animals.	20	Animal welfare support/membership, kindness to animals	Ethical existence
5. **Scientistic:** Primary interest in the physical attributes and biological functioning of animals.	1	Scientific study/hobbies, collecting	Scientific
6. **Esthetic:** Primary interest in the artistic and symbolic characteristics of animals.	15	Nature appreciation, art, wildlife tourism	Esthetic
7. **Utilitarian:** Primary concern for the practical and material value of animals.	20	Consumption of furs, raising meat, bounties, meat hunting	Consumptive, utilitarian
8. **Dominionistic:** Primary satisfactions derived from mastery and control over animals, typically in sporting situations.	3	Animal spectator sports, trophy hunting	Sporting
9. **Negativistic:** Primary orientation an active avoidance of animals due to fear or dislike.	2	Cruelty, overt fear behavior	Little or negative
10. **Neutralistic:** Primary orientation a passive avoidance of animals due to indifference.	35	Avoidance of animal behavior	Little or negative

[1] Totals sum to more than 100 percent because some people were strongly oriented toward more than one attitude.

scores they gave to the five top-ranked reasons. Similarly, Haas (1980) found that those Colorado residents who had, and those who had not, visited wildernesses both ranked 13 reasons for protecting wilderness almost identically. Those reasons included maintenance of species diversity.

Arthur (1979) too, in a national survey (of 2,460 respondents), asked the subjects to rate the importance of several aspects of wildlife on a 0-10 scale where 0 represented "no importance" and 10 "extreme importance." The ratings (and mean values) were: ecological value (8.9), existence value (8.6), viewing pleasure (8.3), food source (4.8), hunting opportunity (3.8), and fur source (2.5). The high ratings given to "ecological" and "existence" values suggest personal and social benefits related to maintaining species diversity.

Hendee and Schoenfeld (1978) proposed three categories of wilderness wildlife: wilderness-dependent, wilderness-associated, and wildlife not dependent or associated. Although no differentiation was made between wilderness-dependent and other wildlife in the Kellert, Shaw, and Arthur studies, it seems reasonable to propose that preservation of species of wildlife that are wilderness-dependent were valued as strongly and for similar reasons as non-wilderness wildlife were in those three studies.

Regarding a wilderness-dependent species, the grizzly bear, Kellert (1979) found in his national survey that 56 percent of the respondents agreed with the statement, "It has been suggested that 5 million acres of National Forest land be set aside so that the endangered grizzly bear remain undisturbed. The timber industry objects, saying that jobs and needed lumber will be lost. Would you agree to protect the endangered grizzly bear even if it resulted in the loss of some jobs and building material?" It is not known how the wording of the question influenced the responses, for example, how "the loss of **some** jobs and building materials [emphasis added]" was interpreted by the respondents. Results showed 9 percent agreed strongly, 26 percent agreed, 21 percent agreed slightly, and 5 percent were neutral. Directly related to wilderness also was another question in the same study that solicited agreement (44 percent) and disagreement (51 percent) with the statement, "Natural resources must be developed even if the loss of wilderness results in much smaller wildlife populations."

Although these public surveys help point out probable benefits of species diversity, the most convincing arguments for species preservation come from data on the numbers of species that exist, what is not known about most of them, the rate at which they are disappearing, and more importantly the contributions that species of animals and plants have made to medical, agricultural, and industrial progress in the past. Myers (1979) has offered an excellent discussion of these considerations.

According to Myers (1979), the number of species of plants and animals on earth in 1960 was estimated to be about 3 million, and currently there are about 5 to 10 million, with 2 to 6+ million estimated to be in the tropics. He points out, though, that in 1978 only about 1.6 million species had been classified. This means that from one-sixth to one-third of the species thought to exist today have not been identified, so nothing is known about their potential benefits to humans.

Myers also points out that species extinction has been occurring for millions of years; mass extinction about 70 million years ago wiped out about one-quarter of all families, including the dinosaurs and their kin, and some 5 million years ago there may have been one-third more bird species than today. His conclusion is that although the pace of speciation has speeded up "the evolutionary record does not show a steady upward climb in earth's total species, rather a series of step-wise increases" (p. 28).

Myers then suggests that humans caused few species to vanish until at least A.D. 1600. He estimated that by 1900 humans were driving one species extinct every 4 years, and thereafter the rate increased to about one per year; these figures refer to mammal and bird species humans knew existed. He estimates that by the year 2000, one million species will vanish. This is supported by a Smithsonian Institution study (Jenkins and Ayensu 1979) that indicates 10 percent of the plant species in the United States are in jeopardy.

To give temporal dimensions to this increased rate of extinction, Myers (pp. 29 and 30) asks the reader to

> ...suppose the whole existence of the planet earth is compressed into a single year. Conditions suitable to life do not develop for certain until May, and plants and animals do not become abundant (mostly in the seas) until the end of October. In mid-December, dinosaurs and other reptiles dominate the scene. Mammals, with hairy covering and suckling their young, appear in large numbers only a little before Christmas. On New Year's Eve, at about five minutes to midnight, man emerges. Of these few moments of man's existence, recorded history represents about the time the clock takes to strike twelve. The period since 1600 A.D., when man-induced extinctions have rapidly increased, amounts to 3 seconds, and the quarter-century just begun [1975-2000], when the fallout of species looks likely to be far greater than all mass extinctions of the past put together, takes one-eighth of a second—a twinkling of an eye in evolutionary times.

Although this quote makes one pause and reflect about the role of humans in the grand scheme of things, and perhaps think about our moral and ethical ecological obligations, it does not address the question: What difference does it make if we lose species diversity or specific species?

Myers addresses this question by first considering esthetic and ethical arguments for species preservation while suggesting that humans might desire to see some organisms disappear, like those that cause the common cold and contribute to cancer. He, as have others (Salwasser 1983), also points out that particular species can serve as indicators of environmental change with the most sensitive, including humans, being near the end of the food chains, so they can flash "a red light concerning new threats to our welfare." Characteristically, Myers raises a caveat (p. 51): "But if indicator species can offer us answers to questions we scarcely know how to ask, how are we to pick out the species that serve this valuable function?" The implication is we should be prudent in leading any species to extinction. The conclusion of Brown and Goldstein (1984) supports that suggestion. Because of much uncertainty, they were unable to show how economic valuations can help in deciding which species to save.

Myers' central argument for preservation of species diversity is quite utilitarian. It is based on the benefits provided to humans by previously "unbeneficial" plants and animals, especially health-related benefits, benefits to increased agricultural stability and productivity, and to industrial processes. He states (p. 60) that "it is the skills of plant geneticists, rather than large amounts of artificial additives, such as pesticides and fertilizers, that have led to one record after another in crop yields in North America and other regions of both temperate and tropical zones." He gives many examples of how new species and varieties have either contributed to agricultural productivity or have the potential to do so, for example:

1. Sorghum productivity took a big leap forward following analyses of 9,000 forms of sorghum that produced two types rich in lysine (an amino acid).
2. A strain of barley has been developed that can grow in sand dunes and be irrigated with sea water.
3. Forms of commercial wheat evolved from primitive wheats found in Asia Minor, where disease-resistant varieties have also evolved.
4. More than 250 cases of partial or complete control of insect pests and weed problems have been documented through the introduction into North America of predator or parasite species.
5. Introductions into the United States of a wild strain of wheat resistant to common and dwarf "bunts" and several other diseases and of a fresh strain of onions resistant to thrips disease have together been estimated to be worth $53.5 million annually in increased productivity (farm gate value).

Examples mentioned by Myers of benefits to medical science include:

1. As many as one-half of all prescriptions written in the United States each year contain a drug of natural origin. These include anticoagulants, antibiotics, heart drugs, antileukemic agents, enzymes, and hormones.
2. Studies of animals also offer medical clues to the origins and nature of disease and to preventative mechanisms. Elephants have helped increase understanding of atherosclerosis and problems of fatty acids. Primates are especially valuable to medical research because of their relatedness to humans. Furthermore, the armadillo is the only animal other than humans known to get leprosy.

These medicinal values are reported by the many researchers referenced by Myers and by others such as Dasmann (1978), who states:

> The precise value of species that are still little known is impossible to predict, but it is well to remember that medical science now makes use of species once considered worthless—that might easily have been allowed to become extinct on the grounds that they were "good for nothing." The present use of *Penicillium* mold (antibiotics), Rhesus monkeys (blood groups), sea urchins (embryology), cinchona bushes (quinine), *Xenopus* toads (pregnancy tests), *Strychnos* vines (curare), foxgloves (digitalis), and *Rauwolfia* (hypertension) could not have been predicted (except perhaps by practitioners of folk medicine, who were familiar with the curative properties of many of these species). Similar contributions are made by wild species to agricultural production, to pest control, and to the development of new domestic varieties. Each species is a storehouse of irreplaceable genetic material whose loss we cannot afford.

Continuing in a very utilitarian vein, Myers also gives examples of industrial products made from wild species: latex products (rubber), pectins, resins, gums and other exudates, essential oils for flavors and related juices, vegetable dyes and tannins, vegetable fats, insecticides, growth regulators, plant-based lubricants, and fuel.

Despite new discoveries each year of the agricultural, medical, and industrial benefits of wild plants and animals, most species have not yet been studied. If such species are not preserved, any latent benefits will be irrevocably lost. The probability of new beneficial discoveries increases as the state-of-the-art of genetic engineering (gene splitting, etc.) continues to advance rapidly (Weaver 1984).

Again, we do not mean to imply that all of the benefits of species diversity discussed can be attributed to wilderness preservation, especially since only a small percentage of Earth's species are found in wilderness in the United States, the focus of this paper. We attempt only to make the point that we do not know what future benefits, especially of a utilitarian nature, might be created by new discoveries. For this reason alone it seems prudent to preserve species diversity. The argument could be made that if there were no other benefits of wilderness preservation in the United States, such preservation could be justified solely on the grounds that we need to demonstrate good faith to other countries on whom we are primarily dependent for novel sources of germ plasm. We have no idea of how large such a U.S. system of demonstration wilderness should be, but it should include representative ecosystems to serve this purpose meaningfully.

Air Visibility.—The 1977 amendments to the 1970 Clean Air Act implicitly recognized the benefits of maintaining clean air and protecting scenic vistas by requiring that standards for air visibility be established over "nationally significant natural areas." These Class I areas include primarily our wilderness areas and National Parks. Although no direct research has been done to specify and quantify these benefits, Driver and others (1979) proposed that these benefits relate to maintenance of conditions necessary for the realization of other benefits sought in the protected areas, namely being able to see out from vistas (esthetics), to orienteer (self-sufficiency), and to protect the wilderness gestalt on which spiritual and other benefits (stewardship) depend.

Ross and others (1983) found that when air visibility (standard visual range) was reduced at the Grand Canyon National Park the visitors noticed it, and many told the National Park Service interpreters that their enjoyment was compromised. They reported too that of 24 park attributes listed, clean, clear air was the third most important attribute (following cleanliness of the park and deep gorges), with 82 percent of the respondents saying it was very to extremely important. The summary of another report (Ross and Malm 1983) that included results of a study of Mesa Verde National Park states, "Results... showed that the majority of respondents at both parks indicated they were aware of haze and that awareness detracted from their overall park enjoyment." Thus, if maintenance of air visibility is not a benefit itself, it is a facilitator of other benefits.

Economists have made several studies attempting to determine the monetary worth of air visibility (Rowe and Chestnut 1983; Schultze and others 1983). Those economic valuations are part of the Economic Benefits section considered later, but we mention them here as support for air visibility benefits, because so little research has been done on that topic.

Unique Landforms, Historic Sites, Educational Values, and Options for Research.—The Wilderness Act defines wilderness along four dimensions, with the fourth stating wilderness areas "may also contain ecological, geological, or other features of scientific, educational, scenic or historical value." Some of these benefits of wilderness were listed separately in our taxonomy, because of their individual importance. They are combined here because little systematic research has been done on them beyond that discussed under the section on Personal Benefits.

Unique landforms are preserved in many wilderness areas, especially in the National Park System, and many of these areas (Yellowstone, Grand Canyon, and Yosemite) are valued internationally for their unique geological features and their scenic values. As documented under the section on Esthetic/Creativity Personal Benefits, evidence abounds that preferences for unique landforms, including scenic resources, in wilderness areas are strong, and use of such areas is high. On-site users spend literally millions of dollars each year on obtaining photographs of such areas, and scenic quality is frequently the most important characteristic of popular tourist destinations. Furthermore, oil, watercolor, and acrylic paintings of these resources are extremely popular as are articles and entire coffee-table volumes featuring them. Also, scenic wildland backdrops are used in advertisements for many products.

Despite these evidences of social value, we found no systematic research to describe the collective or social benefits of preserved unique landforms. Nevertheless, we retained this category of benefit because its generic qualities permit strong inference of considerable social benefits of a synergistic nature. This concept was expressed in the Outdoor Recreation Resources Review Commission (1962) report on wilderness several years before the Wilderness Act was passed: "It seems manifestly true that the real worth of any exceptional thing lies not alone in its entity but as well in the influence it casts over an array of things." Specifically, novelty of geological formation, vastness of scale, and scenic beauty interact with other features of wilderness to create a whole that is greater than the sum of the parts. Part of nurturance, existence, and bequest benefits related to wilderness are associated with desires to preserve and pass on to future generations this uniqueness and beauty. However, these dimensions are difficult to parcel out discretely from other aspects, such as maintenance of species diversity, simply because a wilderness is a system that functions as a whole because of the interdependency of its parts. Similarly, the concept and benefits of wilderness as a cathedral, or sacred place (Graber 1976), are frequently associated with sites at which spectacular features, including outstanding scenery, are part of a gestalt that loses some meaning with dissection or scientific reduction. Although some dimensions of personal benefit can be analyzed and assumptions made about aggregate contributions to social welfare and increases in the quality of American life, essentially one is left primarily with strong inferences about social benefits based on pervasive indicators.

Although most of the educational benefits of wilderness are of a personal nature, there are most certainly social benefits, too. Probably the most significant is better collective appreciation by a society of its dependency on ecological processes for basic life-support systems. Such understanding from any source can help deter environmental modifications that adversely impact human welfare. Less related to survival and more qualitative in nature are the learning benefits that contribute to any collective environmental ethics that are shared and valued by many in a society.

The major scientific benefits of wilderness preservation are probably those that can (and will in the future) be attributed to maintenance of species diversity. Because many wilderness areas have not been modified greatly by human activity, they also offer unique opportunities for scientific studies of natural processes in relatively undisturbed areas. As the ORRRC (1962) wilderness report points out, many concepts of ecology

> ...are founded on conditions resulting from natural processes.... Such conditions are more closely maintained in areas where primarily indigenous species are represented and where the ecology is "system-dependent." That is, the interactions among species and between them and their environment depend on processes generated by the system itself. Such system interactions are not possible in most of the small "natural areas" set aside throughout the country, but they are approximated in extensive wilderness areas.

This statement was made before passage of the Wilderness Act and was addressed to acreages much larger than 5,000 acres, so it applies to many but not all designated and undesignated wilderness.

In addition to being relatively undisturbed natural laboratories for research on the history, structure, and functioning of whole ecosystems, wildernesses also provide settings for the study of characteristics of individual species and their environmental requirements. They serve also as indicators of environmental trends, whether in reduced air visibility or increases in the adverse impacts of acid rain on plant and animal species and communities. They provide control, or comparison, areas in hydrologic studies of effects of vegetative manipulation on water flows and of the characteristics and dynamics of wildfires and of infestations of insects and diseases.

Stewardship Benefits.—Social stewardship benefits comprise a subcategory of preservation-related benefits that accrue both to individuals and to a society from knowing actions are being taken to preserve options for current and future generations to enjoy and use wilderness resources; to respect the "rights" of nonhuman organisms to live; and even to grant that these organisms themselves benefit from preservation efforts. Although largely symbolic (see discussion under Personal Benefits), these benefits go beyond concerns for future generations and include the notion that humans have responsibilities to recognize and appreciate their place in nature and to temper the notion of human supremacy and "power to have dominion" in the short run.

Many people believe that a society is wrong-headed—with confused values and an unrealistic perspective about its long-term destiny—if it doesn't preserve some areas. Evidences of stewardship benefits can be interpreted from the reasons reported for preserving wildlife (under Species Diversity Benefits) in the Kellert, Shaw, and Arthur studies. These stewardship benefits have been pervasively espoused in the past (Marsh 1864; Muir 1916; Marshall 1930) and still are in the current literature (especially the Journal of Environmental Ethics). Perhaps the most articulate and influential spokesperson for these ideals was Leopold (1949), with his call for a land ethic. These beliefs are reflected in part by the diverse and significant environmental legislation passed in the 1960's and 1970's. These wise stewardship values have apparently increased in significance: new organizations espousing these values (Friends of the Earth, Fund for Wildlife) have emerged; these values are reflected in the Secretary of Interior's 1986 campaign to "Take Pride in America," and they are projected to constitute a primary recommendation of the President's Commission on Americans Outdoors (Jordan 1986).

Quality of Life Benefits

Another category of probable social benefits that has been addressed in the early literature, but infrequently in recent studies focusing on wilderness (McCloskey and Gilligan 1969), is what has been called improvements in the overall quality of life. This, a rather abstract concept, has emerged from research on factors perceived to contribute to overall life satisfaction of the respondents. Those studies (Campbell 1982) show the top five contributors to life satisfaction are economic security, marital/family relationships, health conditions, self-concept, and environmental amenities. It seems reasonable to conjecture, until more wilderness-specific research is done, that wilderness preservation is a contributing factor to the environmental amenities component of a quality life for many on- and off-site users.

Commodity-Related Benefits

In addition to preservation-related benefits, society reaps many advantages from the goods produced from wilderness areas. Designated wilderness areas protect the headwaters of many regionally and nationally important rivers, and impoundments are found in some areas. Although constrained by the Wilderness Act, mineral and grazing-related commodities are also produced on these areas as are opportunities for commercial recreation. These and other commodities, including timber products, are produced from nondesignated wilderness resources, and these commodities are used because of the benefits they produce.

The argument is sometimes made that designated wildernesses cause inappropriate and unnecessary costs to society because they lock up resources with commodity values, especially minerals and timber. Because our purposes are to look at the benefits, rather than the costs and the net benefits of wilderness, we will not address that argument. We will suggest, though, that several studies have indicated that the timber-related opportunity costs (for example, forgone benefits) of wilderness are relatively small for a moderate-sized wilderness preservation system (Teeguarden 1981) or can be offset by more effective management of nonwilderness lands (Hyde 1983). If these costs should become socially excessive, the American people through Congress can in the future change provisions of the Wilderness Act.

Economic Benefits

Benefits to National Economic Development.—Benefits were defined in this paper as improvements in conditions of individuals or society or the prevention of deterioration in desired conditions. We have focused on the improved conditions rather than the economic worth of the wilderness-related goods and services that provide these benefits, which has been the concern of economists studying how wilderness use (including off-site use) contributes to national economic development or welfare. These contributions to national economic welfare are indexed by consumers' willingness to pay for the wilderness-related goods and services. This economic information is useful in ascertaining whether economically efficient allocations of public resources are being made in the short run, with such efficiency being a desirable state—or beneficial condition. To the extent these economic efficiency analyses do not include the economic worth of all benefits, the estimated worth of benefits reported is inaccurate and the future is discounted inappropriately.

Besides helping prevent wasteful resource allocations, the economic efficiency measures also help index the magnitude of wilderness-related benefits in units commensurate with those used to estimate the worth of other goods and services produced from public lands. Such indexing provides information to the resource allocation process in a form that usefully supplements other information inputs (Randall 1984); for wilderness benefits this has generally been highly subjective or intuitive. The economic studies also are useful in identifying specific characteristics or attributes of wilderness that are most valued.

Although many studies have been made of the economic values of public amenity resources using variations (travel costs, contingent valuation, hedonic methods) of the willingness-to-pay approach (Dwyer and others 1977), a relatively small subset have focused on wilderness. Sorg and Loomis (1984) reviewed and made methodological adjustments to willingness-to-pay data from several economic studies of wilderness recreationists, primarily hikers and backpacking campers. Most of the values (in 1982 inflation-adjusted values using the GNP price index) ranged from $13 to $20 per activity day (a variable portion of each day devoted to the primary trip activity).

Those studies included two by Walsh and his associates. In one, Walsh and others (1984) reported similar values for hiking and cross-country skiing in nonroaded areas on the Roosevelt National Forest in Colorado. Other economic studies of on-site wilderness users have also been made. One study reported visitors to a scenic overview in Bryce Canyon National Park (Utah) were willing to pay $62 to $71 per vehicle (Johnson and Haspel 1983).

Economic studies of preservation efforts have also been made of the existence, bequest, and option values of wilderness resources as expressed by both on- and off-site users (Bishop 1982; McConnell 1983; Randall and Stoll 1983). One of the first, a study of the economic benefits of preserving Hells Canyon of the Snake River by Krutilla (1970), established the significance such data can play in policy formation and public resource allocations. The Krutilla study helped show that the benefits of preserving the Canyon compared favorably with development for other uses. The many subsequent studies include the report by Schultze and eight others (1983) on their household survey of willingness to pay to preserve visibility in Grand Canyon, Mesa Verde, and Zion National Parks; the Walsh and others (1984) household survey in Colorado of the option, existence, and bequest demands for Colorado wilderness; and the Walsh and others (1985) study of Colorado user and nonuser households' willingness to pay for preservation of wild and scenic rivers in Colorado.

Other economic studies of on- and off-site wilderness users provided increased knowledge about specific components of wilderness that are most highly valued. An example is the Walsh and Gilliam (1982) study of the effect of congestion on willingness to pay by users in the Indian Peaks Wilderness in Colorado.

Practically all of the wilderness-related economic studies reviewed reported relatively large willingness-to-pay values for the preservation efforts studied. Whether or not the techniques used provide dollar indices of benefits with desired accuracy and validity is a moot point at this time, as these recently developed techniques are being refined. Nor do we assume that the techniques index the monetary worth of all benefits such as those unknown to the respondent, the synergistic contribution of one type of wilderness benefit to the holistic bundle of benefits realized by an individual, and especially any spinoff benefits to society collectively not appraised by the individual consumer when estimating his or her willingness to pay for a specified preservation action. Despite these problems, the results indicate sizable economic values, which we believe are related to benefits the respondents perceive they obtain.

Benefits to Regional and Local Economic Development.—In addition to the just-described contributions that wilderness-related goods and services make to national economic development, wilderness resources, especially superlative and unique features, serve as significant tourist attractions in many localities. They, thereby, contribute to local and regional economic development through their positive impact on area income and employment.

Most States report that tourism/recreation is a leading industrial sector, generally in the top five, and in many States in the top three, in terms of income and employment generated. Although much of these leisure and leisure-related industries are resource-based, it is difficult to parcel out the contribution of wilderness for many reasons. The most troublesome is that tourist/leisure-related industries do not have separate codes in the U.S. Office of Management and Budget's industrial classification system (OMB 1972). Because employment and income generated by these industries is attributed to the other classified sectors within which the tourism-related industries are subsumed, it is difficult to track the economic contributions of these industries. Another accounting difficulty stems from the fact that economically viable tourism complexes offer a variety of activities, interests, and services that interact to form a critical mass (Horvath 1970). The problem with respect to apportioning benefits to wilderness and other attractions is that of knowing relative contributions of each component to the whole, just as it is almost impossible to attribute the contribution of a particular group of musical instruments to the overall quality of a successful symphony orchestra. Lastly, there still is a Protestant ethic bias that discounts the contributions of "play-related" industries to economic growth.

Despite these problems, leisure industries are big business in the United States and most other countries. The proportion represented by wilderness-dependent and wilderness-associated tourism has not been determined. But with the rapid growth in outdoor recreation visitation and expenditures since World War II, especially in dispersed recreation, the contribution of wilderness resources to regional and local economic development is certainly appreciable. However, the other side of the coin is that tourist developments can conflict with the realization of wilderness benefits. The contextual question arises again about whose values define the benefits.

INHERENT/INTRINSIC BENEFITS

This last and least anthropocentric category of benefits of wilderness derives from the notion that nonhuman organisms benefit from wilderness protection—and even that components of the wild ecosystem have interests, perhaps even rights, that humans should respect (Callicott 1985; Leopold 1949; Stone 1974). The roots of this concept in the United States lie in the thoughts of Henry David Thoreau and John Muir (Nash 1982). Albert Schweitzer's "reverence for life" axiom is relevant here, as is Aldo Leopold's "land ethic" and Alfred North Whitehead's "process philosophy." More recently, the Gaia hypothesis—the idea that the Earth as a whole is an organism to which humans belong—gives unprecedented reasons for respecting wilderness (Lovelock 1979). Also germane is the perspective of the "deep ecologists," whose biotic equalitarianism challenges the fundamental premises of anthropocentrism. However, many professional philosophers, such as Lehmann (1981), raise serious objections to these concepts.

On a popular level what the intrinsic value of wilderness signifies is the need for human restraint. Wilderness, in fact, may be the best place to learn that we are members, not masters, of the life community sharing a common habitat and that achievements have been made in the evolutionary process that have resulted in other stories beyond the human story. Permitting wilderness to exist becomes a gesture of planetary modesty, an expression of humility and gratitude in the face of realities that transcend the short and probably ephemeral human endeavor—the need to recognize some values beyond our human range and scope, such as admiration for overwhelming powers (thunder, waves, sunsets) and skills more developed than our own, such as speed, smell, and endurance (Rolston 1986). A wilderness testifies to the ability of technological civilization to control its capacity for total modification of the Earth. This may be a most meaningful benefit of a preservation policy.

Summary on Knowledge About Benefits

Although we were not always able to reference scientific studies to document the benefits of wilderness considered within our taxonomy, enough research exists to support the firm conclusion that wilderness-related benefits are extremely broad in scope. Because of limitations of the state of knowledge, no firm research-based conclusion can be made about the magnitude of some of these benefits. For some, such as the benefits of preserving species diversity, past contributions to medical, agricultural, and industrial productivity attest to the prudence of avoiding species extinction. For others, such as the therapeutic benefits of wilderness, tremendous untapped opportunities for benefits likely exist. Furthermore, users' willingness to pay for wilderness preservation and for on-site recreational use of wilderness attest to sizable benefits, as do several national surveys showing strong support for wilderness preservation.

Certainly more research is needed to document further the presence or absence of benefits within each class of our taxonomy. Our priorities for that research are reflected in the section that follows. That section also gives our interpretations of categories of benefits that are most relevant to wilderness preservation and to promotion of a wilderness philosophy.

WILDERNESS DEPENDENCY OF BENEFITS

This final section interprets our judgments about which categories of benefits are the most wilderness-dependent and therefore most useful in promoting a sound wilderness philosophy.

From our taxonomy of benefits, we will select and consider briefly those we judge to be the least and the most wilderness dependent. This does not mean that the less dependent values cannot be attributed to wilderness; they can if provided by wilderness. Nevertheless, the most dependent values are those that will best support the promotion of a wilderness philosophy. In the past, the wilderness movement has not always led from it strengths. We must do a better job of articulating the most central wilderness values, especially now as attention focuses on development of agency guidelines and standards for wilderness management and as pressures for alternative uses continue to increase.

Less Central Values

We believe the following benefits attainable from wilderness are less central to promoting a wilderness philosophy: (1) some, but not all, benefits related to skill and self-concept development, therapy, physical health, and social identity; (2) most of the scenic landscape dimensions of the esthetic benefits; (3) those general recreation and nurturance benefits attainable in alternative areas; (4) air visibility benefits; (5) most of the commodity-related benefits; and (6) perhaps even some of the bequest-related benefits.

Except for some of the challenge-type programs and opportunities provided for a particular mode of self-sufficiency, other of the self-concept benefits are not very wilderness dependent. Nor are most outdoor recreation opportunities that contribute to stress mediation, physical fitness, and social interaction. A problem with viewing wildernesses primarily as public outdoor recreation areas is that policy can lead to overuse and diminish opportunities to realize other, what we consider higher, wilderness values.

Although preservation of areas of outstanding scenic beauty is mentioned in the Wilderness Act, we believe that value might be stressed too much. Scenic beauty is not an essential component of wilderness; the absence of civilization is. Now some do find the absence of civilization beautiful, but many others who like wilderness find it weird, strange, mysterious, frightening, harsh, and decidedly unlovely. Edward Abbey, for instance, seldom mentions scenic beauty in his paean to the desert canyonlands of the Southwest. John Muir and the Sierra Club lost the 1913 controversy over Yosemite's Hetch Hetchy Valley because they phrased its defense largely in terms of scenery (Nash 1982). This allowed San Francisco to reply that the dam and reservoir it wanted to build on the Tuolumne River would improve the scenery—reflect it double in fact. Muir would have been better advised to rest his case on the wildness of the valley. The point is that "providing scenic beauty" is not as central as those values that depend specifically on the wildness of an environment. The tendency to think of wilderness as beautiful also complicates the task of managers trying, for instance, to convince the public that fire has a natural place in a wilderness ecosystem.

Arguments about the water and air-visibility benefits of wilderness also do not seem central to promotion of a wilderness philosophy. Good water and air are not dependent on wilderness as are the existence of wolves and grizzlies. Excellent water can come from the vast concrete catchments proposed for parts of the Arizona desert. Water and air are useful arguments, and ones that the public and the politicians readily understand and support. However, if we lean too heavily on them in the defense of wilderness, we run the risk of having that leaning post cut off.

Another possible flaw in the way we commonly defend wilderness is to argue that future generations would mourn its disappearance. But how do we know this? Perhaps appreciation of wilderness will atrophy as it apparently has, for example, among many Europeans and

Chinese. Perhaps people of the future will really prefer to get their wilderness experience from cassette tapes of wind in the pines and videotapes of campfires played on the living room television. It might be better to base the defense of wilderness on historical experience rather than on a hypothetical future valuation. Let's protect and manage wilderness because it is important to us, now. It is good stewardship to pass along options for choices—prevent irreversibilities—but we should exercise care in assuming what those future generations will in fact value and choose.

Finally, although we recognize and support the need—even requirement—of Federal agencies to determine the economic efficiencies of different resource allocations, we do not believe that promotion of national economic development can be a notion central to a wilderness philosophy, at least in the near future. Many wilderness values are not amenable to valuation within the context of market exchange, and there are other economic measurement problems to resolve.

Because of the limited state of the art for measuring all wilderness benefits, the need will continue to exist for some time to defend wilderness resource allocations primarily in the political arena. To do that well—and to guide wilderness management adequately—the most central wilderness values must be articulated.

Most Central Values

Of the many types of wilderness benefits we described, six seem to us to represent the core of a wilderness philosophy. Each is wilderness-dependent, historically valid, shaped by an understanding both of the realities of wilderness and of the needs of civilization, and intuitively clear (with the possible exception of the last one listed). They are:

1. Preservation of representative national ecosystems and maintenance of species diversity as laboratories for links with the past, learning, and scientific research, and as models for appreciating the complex, interactive, supportive, and competitive forces that maintain life without the need for human assistance.
2. Spiritual values that capture the themes of natural cathedrals, understanding unity and continuity, celebrating the creative forces behind life, and realizing the spiritually sustaining and cleansing powers of natural areas.
3. Esthetic values that go beyond scenic beauty to the sublime—to the notions of awesomeness, majesty, and overwhelming esthetic impact.
4. Inherent/intrinsic values which, if they do not adequately articulate, at least gently hypothesize that nonhuman organisms have their places on Earth and that perhaps even inanimate objects have the right to exist. Wilderness preservation, as a form of restraint, helps temper the tendency of aggressive humankind to conquer and subdue the entire Earth.
5. Historical and current cultural values nurtured by wilderness, such as freedom, pride in one's nation's material bounty and splendor, creative inspiration, and maintenance of a part of the past out of respect for what has been.
6. Specific types of recreational use that depend on wilderness settings, including the quest for self-sufficiency, particular types of challenge and skill-testing, and recreation and therapeutic benefits related to being in a tranquil, serene, primitive area with few other people around.

It is our conviction that these six benefits constitute the basis of a wilderness philosophy. If they are not accepted and acted upon, the remaining wilderness will fall victim to the same utilitarian pressures that have modified most of the American environment. Finally, let us emphasize that all six arguments are made the more telling by the fact of the scarcity of wilderness.

This is 1985, not 1885 or 1685. The frontier is gone. The amount of pavement in the 50 States is approximately equal to the amount of designated wilderness. There is much of which to be proud in this fact; we have indeed made the crooked straight and the rough places plain. Eliminating wilderness defined human success for thousands of years. It was what the old frontier was all about. But just as the conquest of wilderness inspired the old frontier, the conquest of civilization should inspire the new frontiersmen. It is now civilization, not wilderness, that needs taming. But we must always remember that the wilderness movement is not against civilization; it is for a satisfying, sustainable civilization. Continued investigation of wilderness benefits will help clarify this ongoing relationship. Although research is needed on all benefits, greater attention is particularly needed on the six central values, even though they are the most difficult to quantify.

REFERENCES

Abbey, Edward. Desert solitaire. New York: Ballantine; 1968. 303 p.

Anderson, Linda M. Land use designations affect perception of scenic beauty in forest landscapes. Forest Science. 27(2): 392-400; 1981.

Arthur, Louis M. The esthetic value of wildlife: perceptions of the American public and sportsmen. In: Daniels, Terry C.; Zube, Ervin H.; Driver, B. L., tech. coords. Assessing amenity resource values. General Technical Report RM-68. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1979: 32-34.

Barcus, Carolyn G.; Bergenson, Roland G. Survival training and mental health: a review. Therapeutic Recreation Journal. 6(1): 3-7; 1982.

Bishop, Richard C. Endangered species and uncertainty: the economics of a safe minimum standard. American Journal of Agriculture Economics. 58: 10-18; 1978.

Bishop, Richard C. Option value: an exposition and extension. Land Economics. 58(1): 1-15; 1982.

Brandborg, Stewart. On the carrying capacity of wilderness. Living Wilderness. 82: 28-33; 1963.

Brown, Gardner, Jr.; Goldstein, Jon H. A model for valuing endangered species. Journal of Environmental Economics and Management. 11: 303-309; 1984.

Brown, Perry J. Psychological benefits of outdoor recreation. In: Kelly, John R., ed. Social benefits of outdoor recreation. Urbana-Champaign, IL: University of Illinois, Department of Leisure Studies; 1981: 13-17.

Brown, Perry J.; Haas, Glenn E. Wilderness recreation experiences: the Rawah Case. Journal of Leisure Research. 12(4): 229-241; 1980.

Brown, Thomas C. The concept of value in resource allocation. Land Economics. 60(3): 231-246; 1984.

Buccola, Victor A.; Stone, William J. Effects of jogging and cycling programs on physiological and personality variables in aged men. Research Quarterly. 46(2): 134-139; 1975.

Bultena, Gordon; Lucas, Robert; Hathway, William. Recreation in the Upper Great Lakes area: a summary of social research. In: Outdoor recreation in the Upper Great Lakes area: Proceedings of a seminar in research needs; 1961 May 11-13; St. Paul, MN. Station Paper 89. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1961: 17-38.

Burch, William R., Jr. The play world of camping: research into the social meaning of outdoor recreation. American Journal of Sociology. 70: 604-612; 1966.

Burch, William R., Jr. Urban children and nature: a summary of research on camping and outdoor recreation. In: Children, nature, and the urban environment: Proceedings of a symposium-fair; 1975 May 19-23; Washington, DC. Washington, DC: U.S. Government Printing Office; 1977: 101-111.

Burton, Leslie M. A critical analysis and review of the research on Outward Bound and related programs. New Brunswick, NJ: Rutgers University; 1981. 196 p. Ph.D. dissertation.

Callicott, J. Baird. Intrinsic value, quantum theory, and environmental ethics. Environmental Ethics. 7(11): 257-275; 1985.

Campbell, August. Well being in American society: recent patterns and trends. New York: McGraw-Hill; 1982. 263 p.

Catton, W. The wildland recreation boom and sociology. Pacific Sociologic Review. 14(3): 339-359; 1971.

Cheek, N. H. Variation in patterns of leisure behaviors: an analysis of sociological aggregates. In: Social behavior, natural resources and the environment. New York: Harper and Row; 1972: 29-43.

Cheek, Neil H., Jr. Social cohesion and outdoor recreation. In: Kelly, John R., ed. Social benefits of outdoor recreation. Urbana-Champaign, IL: University of Illinois, Department of Leisure Studies; 1981: 49-53.

Clawson, M.; Knetsch, J. Economics of outdoor recreation. Baltimore, MD: Johns Hopkins Press; 1966. 196 p.

Dasmann, Raymond. Wildlife and ecosystems. In: Brokaw, Howard P., ed. Wildlife and America. Washington, DC: U.S. Government Printing Office; 1978: 18-27.

Ditton, Robert B. The Buffalo National River recreation study: year two. College Station, TX: Texas A. & M. University, Department of Recreation and Parks; 1981. 182 p.

Driver, B. L. Quantifications of outdoor recreationists' preferences. In: Smissen, B. van der; Myers, J., eds. Research: camping and environmental education. HPEP Series No. 11. University Park, PA: Pennsylvania State University; 1976: 165-187.

Driver, B. L.; Brown, Perry J. A social-psychological definition of recreation demand with implications for recreation resource planning. In: Assessing demand for outdoor recreation, Appendix A. Washington, DC: National Academy of Sciences; 1975. 123 p.

Driver, B.L.; Brown, Perry C. Contributions of behavioral scientists to recreation resource management. In: Altman, Irwin; Wohlwill, Joachim, eds. Behavior and the national environment. New York: Plenum Press; 1983: 307-339.

Driver, B. L.; Cooksey, R. W. Preferred psychological outcomes of recreational fishing. In: Catch-and-release fishing as a management tool: a national sport fishing symposium; Proceedings; 1977 September 7-8. Arcata, CA: Humboldt State University; 1980: 27-49.

Driver, B. L.; Knopf, Richard. Temporary escape: one product of sport fisheries management. Fisheries. 1: 21-29; 1976.

Driver, B. L.; Rosenthal, D. H.; Johnson, L. A suggested approach for quantifying the psychological benefits of air visibility. In: Proceedings of workshop on visibility values; 1979 January 28-February 1; Fort Collins, CO. General Technical Report WO-18. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 100-105.

Dwyer, John; Kelly, John; Bowes, Michael. Improved procedures for valuation of the contribution of recreation to national economic development. Report 128. Urbana-Champaign, IL: University of Illinois, Water Resources Center; 1977. 218 p.

Etzkorn, P. Leisure and camping: the meaning of a form of public recreation. Sociological Society Research. 48: 76-79; 1964.

Ewert, Alan. Outdoor adventure and self-concept: a research analysis. Eugene, OR: University of Oregon, College of Human Development and Performance; 1983. 35 p.

Fox, Douglas; Loomis, Ross; Green, Thomas, eds. Proceedings, workshop on visibility values; 1979 January 28-February 1; Fort Collins, CO. General Technical Report WO-18. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 153 p.

Franklin, Jerry F. Wilderness ecosystems. In: Hendee, John C.; Stankey, George H.; Lucas, Robert C., eds. Wilderness management. Miscellaneous Publication 1356. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 191-212.

Frissell, Sidney S.; Duncan, Donald P. Campsite preference and deterioration in the Quetico-Superior Canoe Country. Journal of Forestry. 63(4): 256-260; 1965.

Frissell, Sidney S. The impact of wilderness visitors on natural ecosystems. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. Completion Report.

Gibson, Peter M. Therapeutic aspects of wilderness programs: a comprehensive literature review. Therapeutic Recreation Journal. 1979 Second Quarter: 13(2): 21-33.

Gilligan, James P. The contradiction of wilderness preservation in a democracy. In: Proceedings, Society of American Foresters; 1954 October 24-27; Milwaukee, WI. Washington, DC: Society of American Foresters; 1955: 119-122.

Graber, Linda H. Wilderness as sacred space. Washington, DC: Association of American Geographers; 1976. 227 p.

Grubb, Eric A. Assembly line boredom and individual difference in recreation participation. Journal of Leisure Research. 7(4): 256-269; 1975.

Haas, Glenn E.; Driver, B. L.; Brown, Perry J. Measuring wilderness recreation experience preferences. In: Cannon, Lance K., ed. Proceedings of the wilderness psychology group annual conference; 1980 August 14-15; Durham, NH. Durham, NH: University of New Hampshire; 1980: 20-40.

Haas, Glenn E.; Herman, E.; Walsh, R. Wilderness values. Fort Collins, CO: Colorado State University, College of Forestry and Natural Resources; 1983; Final Report. 11 p.

Hammitt, William E. Cognitive dimensions of wilderness solitude. Environment and Behavior. 14(4): 478-493; 1982a.

Hammitt, William E. Psychological dimensions and functions of wilderness solitude. In: Boteler, Franklin E., ed. Proceedings, third annual conference wilderness psychology group; 1982 July 8-9; Morgantown, WV. Morgantown, WV: West Virginia University, Division of Forestry; 1982b: 50-60.

Heberlein, Thomas A. Density, crowding and satisfaction: sociological studies for determining carrying capacities. In: Proceedings, river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 67-76.

Heberlein, Thomas A. What people mean by wilderness: an exploratory look at word associations. In: Boteler, Franklin E., comp. Proceedings, third annual conference wilderness psychology group; 1982 July 8-9; Morgantown, WV. Morgantown, WV: West Virginia University, Division of Forestry; 1982: 168-183.

Hendee, J. C.; Catton, William R.; Marlow, L. D.; Brockman, C. F. Wilderness users in the Pacific Northwest—their characteristics, values and management preferences. Research Paper PNW-61. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968. 92 p.

Hendee, John C.; Schoenfeld, Clay, eds. Wildlife in wilderness. In: Hendee, John C.; Stankey, George C.; Lucas, Robert C., eds. Wilderness management. Miscellaneous Publication 1356. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 215-247.

Horvath, Joseph C. The role of the private sector in providing recreational opportunities. In: Driver, B. L., ed. Elements of outdoor recreation planning. Ann Arbor, MI: University of Michigan Press; 1970: 145-169.

Hyde, William F. Development versus preservation in public resource management: a case study from the timber-wilderness controversy. Journal of Environmental Management. 16: 347-355; 1983.

Jenkins, Dale W.; Ayensu, Edward. One-tenth of our plant species may not survive. Smithsonian. 5: 92-96; 1979.

Johnson, F. Reed; Haspel, Abraham E. Economic valuation of potential scenic degradation at Bryce Canyon National Park. In: Rowe, Robert D.; Chestnut, Lauraine G., eds. Managing air quality and scenic resources at national parks and wilderness areas. Boulder, CO: Westview Press; 1983: 235-245.

Jordan, Charles. 1986. Personal communication with Mr. Jordan, who is a commissioner on the President's Commission on Americans Outdoors.

Kaplan, Rachel. Some psychological benefits of an outdoor challenge program. Environment and Behavior. 6(1): 101-116; 1974.

Kaplan, Stephen. Attention and fascination: the search for cognitive clarity. In: Kaplan, Stephen; Kaplan, Rachel, eds. Humanscape: environments for people. Belmont, CA: Duxbury Press; 1978: 84-90.

Kaplan, Stephen; Talbot, Janet Frey. Psychological benefits of a wilderness experience. In: Altman, Irwin; Wohlwill, Joachim F., eds. Behavior and the natural environment. New York: Plenum Press; 1983: 163-203.

Kellert, Stephen R. Public attitudes toward critical wildlife and natural habitat issues. Phase I. Report to U.S. Department of the Interior, Fish and Wildlife Service. New Haven, CT: Yale University, School of Forestry and Environmental Studies; 1979. 138 p.

Kellert, Stephen R. Contemporary values of wildlife in American society. In: Shaw, William W.; Zube, Ervin H., eds. Wildlife values. Tucson, AZ: University of Arizona, School of Renewable Natural Resources; 1980. 117 p.

Kellert, Stephen R. Affective, cognitive and evaluative perceptions of animals. In: Altman, Irwin; Wohlwill, Joachim F., eds. Behavior and the natural environment. New York: Plenum Press; 1983: 241-267.

Kelly, John R. Socialization toward leisure: a developmental approach. Journal of Leisure Research. 6: 181-193; 1974.

Kelly, John R. Family benefits from outdoor recreation. In: Kelly, John R., ed. Social benefits of outdoor recreation. Urbana-Champaign, IL: University of Illinois, Department of Leisure Studies; 1981: 44-53.

King, D. Some socioeconomic comparisons of Huron Manistee National Forest campers with market populations. In: Proceedings, Michigan Academy of Science, Art, and Letters. 50: 30-33; 1965.

Knopf, Richard C. Recreational needs and behavior in natural settings. In: Altman, Irwin; Wohlwill, Joachim F., eds. Behavior and the natural environment. New York: Plenum Press; 1982: 205-240.

Knopf, Richard C.; Driver, B. L.; Bassett, John R. Motivations for fishing. In: Transactions of the 38th North American wildlife and natural resources conference; March 18-21, 1973; Washington, DC. Washington, DC: Wildlife Management Institute; 1973: 191-204.

Knopf, Richard C.; Lime, David W. A recreation manager's guide to understanding river use and users. General Technical Report WO-38. Washington, DC: U.S. Department of Agriculture, Forest Service; 1984. 37 p.

Krutilla, John V. Evaluation of an aspect of environmental quality. In: Proceedings of the social statistics section. Washington, DC: American Statistical Society; 1970: 198-206.

LaPage, Wilbur F. Some sociological aspects of forest recreation. Journal of Forestry. 61: 32-36; 1963.

LaPage, W. F.; Ragain, D. P. Family camping trends—an eight-year panel study. Journal of Leisure Research. 6: 101-112; 1974.

Lee, Martha E.; Brown, Perry J.; Manfredo, Michael. Steens Mountain Recreation Area study. Corvallis, OR: Oregon State University, Resource Recreation Management Department; 1982. 95 p.

Lee, Robert G. Alone with others: the paradox of privacy in wilderness. Leisure Sciences. 1: 3-19; 1977.

Lehmann, Scott. Do wildernesses have rights? Environmental Ethics. 3: 129-146; 1981.

Leopold, Aldo. The wilderness and its place in forest recreational policy. Journal of Forestry. 19: 718-721; 1921.

Leopold, Aldo. Sand County almanac and sketches from here to there. New York: Oxford University Press; 1949. 269 p.

Levitt, Lynn. How effective is wilderness therapy? a critical review. In: Boteler, Franklin E., comp. Proceedings, third annual conference wilderness psychology group; 1982 July 8-9; Morgantown, WV. Morgantown, WV: West Virginia University, Division of Forestry; 1982: 81-93.

Lime, D. W. Factors influencing campground use in the Superior National Forest of Minnesota. Research Paper NC-60. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1971. 18 p.

Loomis, John; Walsh, Richard; McKean, John. The opportunity costs of Redwood National Park: comment and elaboration. Contemporary Policy Issues. 3: 103-109; 1984 Winter.

Lovelock, J. E. Gaia: a new look at life on earth. Oxford, England: Oxford University Press; 1979. 157 p.

Lucas, P. H. C. How protected areas can help meet society's evolving needs. In: McNally, Jeffery A.; Miller, Kenton R., eds. National parks, conservation, and development: the role of protected areas in sustaining society: Proceedings of the world congress on national parks; 1982 October 11-22; Bali, Indonesia. Washington, DC: Smithsonian Institution Press; 1984: 72-77.

Lucas, Robert C. The importance of fishing as an attraction and activity in the Quetico-Superior Area. Research Note NC-61. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1963. 3 p.

Lucas, Robert C. Recreational use of the Quetico-Superior Area. Research Paper LS-8. St. Paul, MN: U.S. Department of Agriculture, Lake States Forest Experiment Station; 1964a. 50 p.

Lucas, Robert C. The recreational capacity of the Quetico-Superior Area. Research Paper LS-15. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1964b. 34 p.

Lucas, Robert C. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Natural Resources Journal. 3(4): 394-411; 1964c.

Lucas, Robert C. Use patterns and visitor characteristics, attitudes and preferences in nine wilderness and other roadless areas. Research Paper INT-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 89 p.

Mandell, Lewis; Marans, Robert. Participation in outdoor recreation: a national perspective. Ann Arbor, MI: University of Michigan, Institute for Social Research; 1972. 99 p.

Manfredo, M.; Brown, P.; Haas, G. Fishermen values in wilderness. In: Proceedings, annual meeting Western Association of Fish and Wildlife Agencies; 1978 July 18-20; San Diego, CA. Salt Lake City, UT: Western Association of Fish and Wildlife Agencies; 1978. 52: 276-297.

Manfredo, Michael; Driver, B. L.; Brown, Perry J. A test of concepts inherent in experienced-based setting management for outdoor recreation areas. Journal of Leisure Research. 15(3): 263-283; 1983.

Margules, C. R.; Usher, M. B. Conservation evaluation in practice: I. Sites of different habitats in Northeast Yorkshire, Great Britain. Journal of Environmental Management. 18(2): 153-168; 1984.

Marsh, George. Man and nature. New York: Scribner; 1864. 472 p.

Marshall, Robert. The problem of wilderness. Science Monograph. 30: 141-148; 1930.

Maslow, Abraham. Toward a psychology of being. New York: Harper and Row; 1969. 369 p.

Merriam, Larry C. The Bob Marshall Wilderness Area of Montana - some socioeconomic considerations. Journal of Forestry. 62(11): 789-795; 1964.

McAvoy, Leo H.; Dustin, Daniel L. The right to risk in wilderness. Journal of Forestry. 79(3): 150-152; 1981.

McClosky, Maxine E.; Gilligan, James P., eds. Wilderness and the quality of life. New York: Sierra Club; 1969.

McConnell, Kenneth E. Existence and bequest value. In: Rowe, Robert D.; Chestnut, Lauraine G., eds. Managing air quality and science resources at national parks and wilderness areas. Boulder, CO: Westview Press; 1983: 254-264.

Mills, Allan S.; Massey, Joseph G.; Gregersen, Hans M. Benefit-cost analysis of Voyageurs National Park. Evaluation Review. 4(6): 715-737; 1980.

More, Thomas A. An analysis of wildlife in children's stories. In: Children, nature and the urban environment. General Technical Report NE-30. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977: 89-94.

Mueller, Eva; Gurin, Gerald. Participation in outdoor recreation: factors affecting demand among American adults. Outdoor Recreation Resources Review Commission Report 20. Washington, DC: U.S. Government Printing Office; 1962. 63 p.

Muir, John. Our national parks. Boston, MA: Houghton Mifflin Co.; 1916. 400 p.

Myers, Norman. The sinking ark: a new look at the problem of disappearing species. Oxford, England: Pergamon Press; 1979. 305 p.

Nash, Roderick. The American environment: readings in the history of conservation. 2d ed. New York: Random; 1976. 364 p.

Nash, Roderick. The value of wilderness. Environmental Review. 3(fall): 14-25; 1977.

Nash, Roderick. Wilderness and the American mind. 3d ed. New Haven, CT: Yale University Press; 1982. 425 p.

Office of Management and Budget. Standard industrial classification manual. Washington, DC: Executive Office of the President; 1972. 649 p.

Opinion Research Corporation. The public's participation in outdoor activities and attitudes toward national wilderness areas. Princeton, NJ: Report prepared for the American Forest Institute; 1977. 130 p.

Orwell, George. 1984, a novel. London: Secker and Warburg; 1949. 312 p.

Outdoor Recreation Resources Review Commission. Wilderness and recreation - a report on resources, values, and problems. Study Report 3. Washington, DC: U.S. Government Printing Office; 1962. 352 p.

Peterson, George L. Motivations, perceptions, satisfactions and environmental dispositions of Boundary Waters Canoe Area users and managers. Evanston, IL: Northwestern University, Department of Civil Engineering; 1971. 264 p.

Peterson, George L. Evaluating the quality of the wilderness environment: congruence between perceptions and aspirations. Environment and Behavior. 6: 169-193; 1974.

Randall, Alan. Budget cost analysis as an information system. In: Peterson, George L.; Randall, Alan, eds. Valuation of wildland resource benefits. Boulder, CO: Westview Press; 1984: 65-75.

Randall, Alan; Stoll, John R. Existence value in a total valuation framework. In: Rowe, Robert D.; Chestnut, Lauraine G., eds. Managing air quality and scenic resources at national parks and wilderness areas. Boulder, CO: Westview Press; 1983: 265-274.

Ream, Catherine H. Impacts of backcountry recreationists on wildlife: an annotated bibliography. General Technical Report INT-81. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 62 p.

Roggenbuck, Joseph W. Wilderness user preferences: eastern and western areas. In: Proceedings of wilderness management symposium; 1980 November 13-15; Knoxville, TN. Knoxville, TN: University of Tennessee; 1980: 103-146.

Rolston, Holmes, III. Values in nature. Environmental Ethics. 3: 113-128; 1981.

Rolston, Holmes, III. Are values in nature subjective or objective? Environmental Ethics. 4: 125-150; 1982.

Rolston, Holmes, III. Duties to endangered species. Bioscience. 35(11): 718-726; 1985a.

Rolston, Holmes, III. Valuing wildlands. Environmental Ethics. 7: 23-48; 1985b.

Rolston, Holmes, III. Philosophy gone wild. Buffalo, NY: Prometheus Books; 1986. 269 p.

Ross, David M.; Malm, William C. An assessment of visitor enjoyment and values at Grand Canyon and Mesa Verde National Parks. Fort Collins, CO: Colorado State University, Cooperative Institute for Research in the Atmosphere; 1983; Report No. 4. 13 p.

Ross, David M.; Haas, Glenn E.; Loomis, Ross J.; Malm, William C. Visibility impairments and visitor enjoyment. Fort Collins, CO: Colorado State University, Cooperative Institute for Research in the Atmosphere; 1983; Report No. 5. 17 p.

Rossman, Betty B.; Ulehla, Z. Joseph. Psychological reward values associated with wilderness use: a functional-reinforcement approach. Environment and Behavior. 9(1): 41-65; 1977.

Rowe, Robert D.; Chestnut, Lauraine G., eds. Managing air quality and scenic resources at national parks and wilderness areas. Boulder, CO: Westview Press; 1983. 314 p.

Salwasser, Hal. Grizzlies, elk, eagles: wildlife diversity and the national forests. In: Using our natural resources: 1983 Yearbook of Agriculture. Washington, DC: U.S. Department of Agriculture; 1983: 156-165.

Saylor, John P. Saving America's wilderness. Living Wilderness. 21(59): 1-12; 1956-57.

Schelhas, John Williams, Jr. The role of natural amenities in the wilderness recreational experience in the Chirichaw Mountains. Tucson, AZ: University of Arizona, School of Renewable Natural Resources; 1979. 93 p. Thesis.

Schreyer, Richard; Nielson, Martin L. Westwater and Desolation Canyons: whitewater river recreation study. Logan, UT: Utah State University, Institute for the Study of Outdoor Recreation and Tourism; 1978a. 196 p.

Schreyer, Richard; Roggenbuck, Joseph W. The influence of experience expectation on crowding perceptions and social-psychological carrying capacities. Leisure Sciences. 4: 373-394; 1978b.

Schultze, William D.; Brookshire, David S.; Walther, Eric G.; [and others.] The economics of preserving visibility in the national parklands of the southwest. Natural Resources Journal. 23: 149-173; 1983.

Scott, Neil R. Toward a psychology of wilderness experience. Natural Resources Journal. 14: 231-237; 1974.

Shafer, Elwood L., Jr.; Mietz, J. Aesthetic and emotional experiences rate high with Northeast wilderness hikers. Environment and Behavior. 1: 187-197; 1969.

Shaw, William W. Current research on esthetic values of wildlife. In: Daniels, Terry C.; Zube, Ervin H.; Driver, B. L., tech. coords. Assessing amenity resource values. General Technical Report RM-68. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1979: 27-31.

Shostrom, E. EITS manual for the personality orientation inventory. San Diego, CA: Educational and Industrial Testing Service; 1974.

Sorg, Cindy F.; Loomis, John B. Empirical estimates of amenity forest values: a comparative review. General Technical Report RM-107. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1984. 23 p.

Sparrowe, Rolling D.; Wight, Howard M. Setting priorities for the endangered species program. In: Sabol, Kenneth, ed. Transactions of the 40th North American wildlife and natural resources conference; 1975 March 16-19; Pittsburg, PA. Washington, DC: Wildlife Management Institute; 1975: 142-156.

Stankey, George H. A strategy for the definition and management of wilderness quality. In: Krutilla, John V., ed. Natural environments: studies in theoretical and applied analysis. Baltimore, MD: Johns Hopkins University Press; 1972: 88-114.

Stankey, George H. Visitor perception of wilderness recreation carrying capacity. Research Paper INT-142. Ogden, UT: U.S. Department of Agriculture, Forest

Service, Intermountain Forest and Range Experiment Station; 1973. 61 p.

Stein, Gertrude. Geographic history of America: or the relation of human nature to the human mind. New York: Random House; 1936. 207 p.

Stone, Christopher D. Should trees have standing? toward legal rights for natural objects. Los Altos, CA: William Kaufman, Inc.; 1974. 54 p.

Stone, Edward C. Preserving vegetation in parks and wilderness. Science. 150: 1261-1267; 1965.

Stone, Gregory P.; Taves, Marvin J. Camping in the wilderness. In: Larrabee, Eric; Meyersohn, Rolf, eds. Mass leisure. Glencoe, IL: The Free Press; 1958: 290-305.

Teeguarden, Dennis E. A method for designing cost-effective wilderness allocation alternatives. Forest Science. 27(3): 551-566; 1981.

Turner, Frederick Jackson. The frontier in American history. New York: Knopf; 1920. 215 p.

Ulrich, Roger S. Natural versus urban scenes: some psychophysiological effects. Environment and Behavior. 13(5): 523-556; 1981.

Ulrich, Roger S. View through a window may influence recovery from surgery. Science. 224: 420-421; 1984.

Ulrich, Roger S. Personal communication with Ulrich. 1986.

Wagar, J. Alan. Relationship between visitor characteristics and recreation activities in two National Forest areas. Research Paper NE-7. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1963. 19 p.

Wagar, J. Alan. The carrying capacity of wildlands for recreation. Forest Science Monograph 7. Washington, DC: Society of American Foresters; 1964. 24 p.

Wagar, J. V. K. Certified outdoorsmen. American Forests. 46: 490-492, 524-525; 1940.

Wallwork, S. S. Montanans and selected wilderness issues. Montana Business Research Quarterly. 22(4): 15-18; 1984.

Walsh, John. Germ plasm resources are losing ground. Science. 214: 421-423; 1981.

Walsh, Richard G.; Gilliam, Lynde O. Benefits of wilderness expansion with excess demand for Indian Peaks. Western Journal of Agricultural Economics. 7(July): 1-12; 1982.

Walsh, Richard G.; Loomis, John B.; Gilliam, Richard A. Valuing option, existence, and bequest demands for wilderness. Land Economics. 60(1): 14-29; 1984.

Walsh, Richard G.; Sanders, Larry D.; Loomis, John B. Wild and scenic river economics: recreation use and preservation values. Englewood, CO: American Wilderness Alliance; 1985. 141 p.

Weaver, Robert L. Beyond supermouse: changing life's genetic blueprint. National Geographic. 166(6): 818-847; 1984.

Wellman, John D.; Dawson, M. S.; Roggenbuck, Joseph W. Park managers' predictions of the motivations of visitors to two National Park Service areas. Journal of Leisure Research. 14(1): 1-15; 1982.

Wenger, Wiley D. A test of unmanned registration stations on wilderness trails: factors influencing effectiveness. Research Paper PNW-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1964. 48 p.

Westman, Walter E. How much are nature's services worth? Science. 197: 960-964; 1977.

Wohlwill, Joachim F. The concept of nature: a psychologist's view. In: Altman, Irwin; Wohlwill, Joachim F., eds. Behavior and the natural environment. New York: Plenum Press; 1983: 1-37.

Young, Robert A. The relationship between information levels and environmental approval of the wilderness issue. Journal of Environmental Education. 11(3): 25-30; 1980.

Young, Robert A.; Crandall, Rick. Wilderness use and self-actualization. Journal of Leisure Research. 16(2): 149-160; 1984.

Young, Robert A.; Fry, B. Wilderness: do Illinoisans approve? Illinois Research. Urbana-Champaign, IL: University of Illinois; 1979. 12 p.

Young, Robert; Crandall, Rick. Self-actualization and wilderness use: a panel study. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 385-388.

Zahnizer, Howard. The need for wilderness areas. National Parks Magazine. 29(123): 161-166; 1955.

AUTHORS

B. L. Driver
Research Forester
Rocky Mountain Forest and Range
Experiment Station
Forest Service, U.S. Department of Agriculture
Fort Collins, CO 80526

Roderick Nash
Professor
Department of History
University of California
at Santa Barbara
Santa Barbara, CA 93106

Glenn Haas
Associate Professor
Department of Recreation Resources
Colorado State University
Fort Collins, CO 80526

EVOLVING CONCEPTS AND TOOLS FOR RECREATION USER MANAGEMENT IN WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

Perry J. Brown
Stephen F. McCool
Michael J. Manfredo

ABSTRACT

The principal use management tools and concepts now available to wilderness managers are reviewed, with emphasis on research contributions to their development. Strategies discussed include carrying capacity, recreation opportunity spectra, limits of acceptable change, and experience-based management. Contemporary issues and tools, including information and education, use limits, and monitoring and evaluation, are presented. The need for further research on these topics is noted, followed by a discussion of other important recreation management use issues that need to be studied.

WILDERNESS AND MANAGEMENT: ANATHEMA OR NECESSITY?

It was once important to debate the validity of managing wilderness. For many, management of the wilderness resource was an anathema. If wilderness is a place where the human touch is not laid upon the land, why then should it be managed? If areas are to be set aside for their wildness, then how could they be subject to the control management implies? Wilderness is a locale for natural processes to operate without the intrusion of humans, so why do these same humans speak of management? If management is defined as active manipulation and intervention, then the very essence of wilderness could be lost through the actions of wilderness managers.

Such discussions of the late 1950's and early 1960's were stimulated by the growing debate over the wilderness bill and the report of the Leopold Committee on Wildlife Management in the National Parks (1963). Stewart Udall, then Secretary of the Interior, asked a distinguished panel of scientists to review the intense wildlife management problems existing in several National Parks. The committee, informally named after its chairman, A. Starker Leopold, went far beyond its initial mandate in several recommendations. The Leopold Committee correctly concluded that many problems resulted from imprecise and inexplicit management objectives. Without such objectives, there could be no coherency or direction to any program. The committee itself suggested that National Parks remain "vignettes of primitive America," implying that such areas represent the landscape as it was when European man first inhabited the continent. Others disagreed, recommending that the objective be to allow natural processes to operate to the extent feasible: parks and wildernesses should be places where one can view the operation and effect of ecological forces unaffected by the influence of human activity.

These issues clearly involved the practical, yet critically important, issue of identifying the appropriate intent for classified National Parks and wildernesses. Whether parks and wildernesses were to be static representations of a landscape at a particular time, statements of the dynamic reality of natural processes, or esthetically pleasing vegetational mosaics was a question demanding resolution. There was no obvious answer.

Stephen Spurr (1963, p. 73), an ardent spokesman for management as intervention, proposed:

> . . . we can continue our present practice of interfering in a limited extent to control fire, spray insects, regulate hunting pressure in wilderness areas, to fish and to regulate water supply. I believe, however, that we should take a more forward looking and constructive view and manage the forest itself skillfully, silently and inconspicuously to modify the forest ecosystem so that it most nearly approximates those types which are desirable from man's viewpoint.

Macinko (1970, p. 239) felt that the issue was really one of degree:

> No doubt the wilderness purist will recoil from the suggestion that wilderness should be managed, but I find no quarrel with some degree of wilderness management—a practice already engaged in—though I would brook far less than Spurr.

This debate unambiguously illustrated how social and cultural values mold the interpretation given to biophysical phenomena. What a park or wilderness is reflects the dominant social view of the day. In periods of social change, more than one interpretation may exist, and such interpretations are often conflicting. Yet, these areas are administered by managers who need clear direction and appreciation of the values represented by classification to effectively and consistently carry out socially acceptable actions.

The recognition generally prevails that management is needed in wilderness, though how much management and what technologies are appropriate are still debated. Immediately following the passage of the Wilderness Act in 1964, the question of how much and what kind of management rose to confront the Forest Service task force formed to write administrative policy for wilderness management. Roth (1984) details how the task force had to deal with the management issue and notes that this task force debated not only the issue of nonconforming uses in wilderness but also the issue of how much management would be permitted. In essence, the task force adopted a "strict constructionist" perspective—if the Wilderness Act did not specifically allow or except a nonconforming use, then the agency would not permit that use in wilderness. A broader interpretation of management opportunities is now taken by the Forest Service.

Several conservation groups have also expressed concerns about the intrusiveness of management technology used to address wilderness management problems. For example, in its recent policy statement, The Wilderness Society recognized the importance of maintaining the wilderness with light-handed techniques:

> Managers should use only those tools, structures, equipment or practices that are the *minimum necessary* to protect the wilderness resource (Frome 1985, p. 225).

Such groups also worry about maintaining a resource which provides "outstanding opportunities for solitude or a primitive and unconfined type of recreation" as originally stated in the Wilderness Act, strongly reinforcing the recognition that the wilderness resource is, in part, an experience, which can be satisfied with only minimal disruptions by management.

It is now widely accepted and recognized, even among environmental groups, that wilderness uses must be managed in order to ensure that the "enduring resource of wilderness" Congress mandated in 1964 is not lost. Zaslowsky (1984) admitted that "the time has long passed when a wilderness area could be legislatively designated and then left alone to the birds and the beasts and the wind."

Indeed, the realization that wilderness must be managed is now not only widely recognized, but also pressed by increasing numbers of groups and individuals. For example, the theme of the National Wilderness Management Conference held in fall 1983 (Frome 1985) was "Keeping What We've Got." And, in their comprehensive study of wilderness managers, Washburne and Cole (1983) clearly identify the need for management of wilderness: over 70 percent indicate that human impacts to vegetation are a problem; 60 percent feel that they have a littering problem; and while over half the managers report no social impact problems, most indicate that recreational use exceeds capacity at least in some places within their wilderness.

The biophysical aspect of wilderness itself often needs little in the way of management, other than to ensure that natural processes are allowed to operate in an untrammeled way. With the possible exception of prescribed, scheduled fire ignitions, there are few explicit actions managers can take to modify the biophysical setting to enhance or maintain wilderness values. However, it is management of the human uses of wilderness, both those identified as compatible and those which are excepted and nonconforming, which has risen to the forefront of concern among environmentalists and managers alike. Essentially, the issue is how much management can wilderness use receive within the philosophical traditions briefly alluded to above?

Such questions become even more difficult to answer for some of the newer, eastern areas included in the National Wilderness Preservation System. For example, the 10,000-acre Indian Mounds Wilderness in east Texas contains roads, oil wells, pipelines, active timber harvest and insect control projects, powerlines, motorboat access, and several other conflicting and nonconforming land uses. How is the wilderness manager to maintain or restore wilderness values when confronted with such an array of uses? How can the manager relate the philosophical traditions of wilderness values to mitigating impacts from these types of uses?

In this paper we review research relating to the principal use management concepts and tools available to wilderness managers. We do this by using research studies to show how wilderness use research has evolved over the past 30 years and especially how it has been related to a search for frameworks to guide management. Our focus is on reviewing research dealing with management of recreational uses rather than on other acceptable or nonconforming uses because, over the wilderness system as a whole, recreational uses provide the major management challenge (Washburne and Cole 1983). There are literally dozens of specific management actions that could be developed in reaction to a particular wilderness problem. Our focus here is on concepts and principles that a manager can use to address wilderness management rather than on description of specific actions, such as campsite obliteration, rehabilitation, or closure. The literature well documents such actions, and several papers reviewed here also address the range of potential actions.

We begin with a look at the evolution of strategies for planning and management such as carrying capacity-based management, the Recreation Opportunity Spectrum and Limits of Acceptable Change processes, and experience-based management. This discussion is followed by a look at research on three contemporary issues—information, use limit policies, and monitoring/evaluation—to illustrate the range of topics being studied and/or needing study today. We conclude by listing some topics that we perceive need study if wilderness management is to be enhanced and if its techniques are to gain legitimacy.

STRATEGIES FOR MANAGEMENT

Essentially two strategies for managing wilderness resources have developed: emphasis on resource protection and emphasis on opportunities for recreation experiences. While we view these as two legs of an integrated management strategy, they often have been separated with arguments made for the rightness of one strategy over the other. We will not repeat this debate. The Wilderness Act (1964) clearly suggests that both resource protection and providing opportunities for primitive and unconfined forms of recreation (an experiential phenomenon—see Driver and Tocher 1970 and Brown 1983) are responsibilities of wilderness administrators.

What is the difference between the two strategies? A strategy for resource protection, emanating from historical concerns about fire protection and human waste and litter (see Dana and Fairfax 1981) and contemporary concerns about environmental quality, preservation of heritage, and preservation of biological stocks, focuses on managing uses, natural phenomena, and impacts to ensure an enduring wilderness resource. In contrast, a strategy for experience-based recreation management, stemming from consumer sovereignty and contemporary concerns with the human condition, focuses on managing uses, natural phenomena, and impacts to provide opportunities for primitive and unconfined forms of recreation. Note that the objects of management are the same while the purposes differ. It is our observation that wilderness research and management have been evolving to integrate both of these perspectives. The discussion that follows should reveal this evolution.

Early Research

Much of the early research (1960-70) regarding wilderness management focused on describing uses, users, and impacts. There was a need to know who was doing what, and where and when they were doing it.

Though not research in the classical sense, Snyder (1966) reported his observations of 14 years of management issues in the John Muir Wilderness. He noted the problems of trails, camping debris, campsites and their dispersal, forage for recreational stock, use of timber by recreationists, administrative sites, use and overuse, and how use might be limited. While not specifying a management scheme, his observations clearly pointed out many of the challenges in wilderness management and led to recognition that research and management were needed in wilderness.

For these early years we might ask, what was done that has been useful in managing either the wilderness resource or the users of wilderness? In the 1960's the Boundary Waters Canoe Area (BWCA) and the larger Quetico-Superior area were under considerable study by Forest Service researchers. This research was pioneering, and the questions asked are still relevant. How are the areas being used; how is wilderness perceived by different types of users; how do use and perceptions of different areas compare? Overriding these questions were concerns about how resources and users were to be managed so that the resource base could be maintained and opportunities for desired experiences provided in the face of rapidly increasing use. Lucas' work was vital for answering these questions. He examined the distribution of all forms of use of the Quetico-Superior area by different types of users and projected future use (Lucas 1964a), related such information to the emerging management concept of carrying capacity (Lucas 1964b), drew implications for management of the various concepts of wilderness held by different kinds of users of the area (Lucas 1964c), began to characterize the changes occurring in recreational use (Lucas 1967), and compared use of the Quetico-Superior area to the Algonquin Provincial Park (Lucas and Priddle 1964). Not only was this work valuable in developing management strategies for the Quetico-Superior area, but it laid a foundation for subsequent research by Lucas and others in other areas.

At about the same time, other researchers were doing equally significant research that would prove helpful to management. Burch (1966) reported on the effect of life-cycle recreational choice, pointing out the changing behavior of recreationists as life cycle progresses. His data showed that remote-camping (wilderness) families represent those just beginning their families and those whose children are leaving home. Merriam (1964) had completed a study of the socioeconomic value of the Bob Marshall Wilderness in Montana, concluding that in 1960 the public interest was best served by reserving the Bob Marshall as wilderness. And Heinselman (1965) was identifying vegetation management possibilities in wilderness and primitive areas.

Toward the end of the 1960's, the Hendee and others (1968) research on wilderness users in the Pacific Northwest was significant. They studied users of three different areas—the Glacier Peak Wilderness, described as a backpackers' area; Oregon's Three Sisters Wilderness, which was a day-hikers' area; and the Eagle Cap Wilderness, which they identified as favored by horse users. The study combined a look at user characteristics and attitudes with identification of preferences for management strategies and actions. The significance of this study, for our purposes, is that it was fairly comprehensive, it identified the location of users along a wildernism-urbanism scale, and it focused on management issues. Among the many findings of the study were: those who were more wilderness purist in their orientation often held different attitudes than not-so-purist recreationists; users of all three areas, though different in their style of wilderness recreation, held quite similar attitudes about management; and the facilities and development interests of many users were not consistent with Wilderness Act specifications. Based on this research, the questions for management are many. How might we handle the development preferences of users in view of the restrictive requirements of the Wilderness Act? Can we manage similar areas with users participating in different styles of wilderness recreation? Whose opinions are to count in management decisions since groups differ in their attitudes and preferences? Also, to what extent do managers perceive accurately the management directives and needs visualized by users?

Hendee and Harris (1970) followed up on this last question and concluded that managers correctly perceived user preferences for many issues, but did differ on some critical issues dealing with behavior, development, and the prevalence of purist philosophies. In a sense, the findings suggest that users are much more flexible regarding management issues than was originally hypothesized.

In another major study Stankey (1971, 1973) examined the characteristics, behaviors, attitudes, and management preferences of users of four wilderness areas—the High Uintas Primitive Area, the Bob Marshall and Bridger Wildernesses, and the Boundary Waters Canoe Area. Much of the focus was on carrying capacity and how one might manage to achieve use within capacity. Later in this paper the carrying capacity aspects of this research are discussed. Here, however, it is appropriate to highlight an attitudinal measurement aspect of the research. Stankey developed a wilderness purist scale to measure how Wilderness Act values were like values of individual wilderness recreationists. His was a multidimensional scale patterned on statements from the Wilderness Act.

Related to this scaling effort was a desire to identify a group of users whose opinions about carrying capacity, management, and wilderness should count. Stankey (1971, p. 274) said:

> By selectively considering the attitudes and perceptions of a population which has the most highly developed appreciation of wilderness values recreation use may be maintained at a

> level consistent with the preservation objectives of the Wilderness Act while also insuring the availability of a high quality wilderness experience. Thus, in examining the question of wilderness recreation carrying capacity, we will focus attention on the strong purists.

An outgrowth of this particular aspect of Stankey's work was a workshop to explore the issue of whose opinions should count in management decision making (Royer and others 1977).

Another area of research that developed fairly early was methodological and dealt with estimating use, identifying spatial and temporal distribution of use, and determining how best to obtain survey information from users. In the area of estimating use, the work of James and others is illustrative (Wenger 1964; James and Henley 1968; Lucas and others 1971). They tested methods of estimating use, including testing the effectiveness of unmanned registration stations and automatic counting devices. Conclusions from this work were that trail registration, when used with regression or ratio estimation procedures, could be calibrated and used to accurately estimate use, and that trail registration would have other benefits in dispersing information to users and collecting information about users and their behavior.

When considering the spatial and temporal distribution of use, the work of Lucas stands out. Much of his work in the Quetico-Superior area described use patterns, including the timing of use and the distribution of use over launch sites, portages, and lakes (Lucas 1964a).

In the area of obtaining valid and reliable survey information, several studies were undertaken dealing with nonresponse bias (Wenger and Gregersen 1964), situational and voluntary response bias (Peterson and Lime 1973), and the appropriate person(s) in the recreational group to interview (Jubenville 1971).

One other area of pioneering research needs to be addressed. In 1970, Lucas (1980) began a series of studies that culminated in a comparison of use patterns and user information across nine different areas. Essentially what began as establishment of baseline surveys for individual areas became a comparative baseline across different types of areas, mostly in the Northern Rockies but also including the Desolation Wilderness in California. This baseline information on users, their behavior, and their perception of the resource enables researchers to measure changes in use and the resource for individual areas. At the same time, since the same baseline information is available for several areas, one can compare conditions across areas and changes across areas over time. It enables putting each area into a broader context, detecting changes unique to one area, and trends in use and resource change over the broader wilderness system.

From a somewhat later period one other piece of literature stands out because it is one of the first to focus on an Eastern wilderness (Leonard and others 1978). The purpose was to describe use characteristics for New Hampshire's Great Gulf Wilderness. In looking at use and its distribution over the area, the study followed much of the pattern of early wilderness research in the Midwest and West.

A lot of stimulating research done from the late 1950's to the early 1970's laid a foundation for subsequent effort at describing the wilderness recreation phenomenon and developing ideas about the management of recreation in wilderness. The research pointed out the need to know much more, and it made it clear that if resources were to be protected, desired experiences were to be realized, and budding conflicts among users were to be reduced, a framework for management of recreation in wilderness was necessary.

Carrying Capacity—Search for a Holistic Management Framework.—Much of the research already identified dealt with the management concept of carrying capacity (Lucas 1964b; Snyder 1966; Stankey 1971, 1973). Carrying capacity was a concept being applied to nonwilderness recreation as well (Wagar 1964), but it seemed well suited to the wilderness situation where there were rather specific concerns about preservation of natural resources and delivery of specific recreation opportunities.

In this context, Lucas (1973, p. 150) indicated that "wilderness cannot survive the draw-a-line-and-leave-it-alone philosophy." It required management focused on its unique qualities to ensure that it was perpetuated. To that end, Lucas (1973) developed a framework for management that was formulated from much of the early research on recreational carrying capacity. In his framework he identified several management principles: (1) maintaining basic ecological processes, (2) controlling visitor impacts, (3) developing the opportunity spectrum, (4) managing the wilderness periphery sensitively, (5) respecting visitors' freedom, and (6) providing opportunities for solitude. Implementing these principles required a holistic view of wilderness management—just the kind of view that the recreational carrying capacity concept was beginning to foster.

One early conclusion was that "the 'preserve' and 'use' dichotomy of the Wilderness Act has created a situation that leaves virtually no alternatives for the wilderness manager to consider other than establishing some 'carrying capacity' for wilderness" (Stankey 1972, p. 98). Wilderness carrying capacity was looked at as deriving from two components, ecological and sociological carrying capacity. Determining ecological carrying capacity would involve investigating changes in the physical-biological aspects of an area due to both natural and human-impact causes; determining sociological carrying capacity would focus on the effects of use on user satisfaction. While these two considerations make up the concept of wilderness carrying capacity, they often have been treated independently by researchers.

From the research on carrying capacity we have learned a lot about both people and management. We will not be able to review all of what has been learned here, but we will try to illustrate some of what has been learned and how that relates to wilderness management.

Lucas' (1964b) work in the Quetico-Superior area set the pattern for much of what was to follow regarding the sociological aspects of carrying capacity. Work by Frissell and Duncan (1965) and others launched the studies of ecological carrying capacity in the wilderness.

Social Carrying Capacity.—Exploring the relationships between environmental variables (social and physical-biological) and peoples' response has been the primary topic of research on social carrying capacity. Much of the emphasis has been further narrowed to the relationship between satisfaction and the number and type of encounters among users.

For example, one outcome of Lucas' (1964b) study was the clear indication that recreationists following different styles of wilderness recreation see issues of crowding and capacity differently, and they use areas differently too. He noted that motor canoeists were less sensitive to crowding than paddling canoeists, and that other motorboaters were even less sensitive to crowding than motor canoeists. He also found that there was differential penetration of the Quetico-Superior area by canoeists, motor canoeists, and motorboaters. This research, from which one might conclude that there are different sociological carrying capacities based on the goals of various groups, established a pattern for looking at the amount, frequency, location, and mode of transport aspects of interactions among recreationists as a way to develop information about perceived crowding (over-capacity use) and its effect on satisfaction.

Stankey's (1971, 1973) research extended this look at differential perceptions of crowding to mountain wilderness areas. From his surveys he found that, in general, users expressed satisfaction with having no contacts with other backpackers while having as few as four contacts was bothersome to 80 percent of the users. There was some differential effect due to style of recreation, with horse user parties somewhat less acceptable than backpacking parties. Stankey also noted that there were perceived effects associated with location of encounter and size of group encountered. He found that interaction along the periphery of wilderness areas was expected and thus more acceptable, and that large groups, which are not the norm in wilderness, had a disproportionately negative effect on visitor satisfaction.

These results were generally replicated in Badger's (1975) study of users of the Rawah Wilderness in Colorado. He went a step further, however, and also determined tolerance levels for encounters between user groups. What he found was that users were willing to tolerate more other groups than they preferred to encounter at a ratio of about 2:1. One might ask, why are they willing to tolerate more than they prefer and still perceive themselves as having a satisfying recreation experience? Satisfaction obviously is a complex concept and several factors contribute to it. First, Stankey (1971, 1973) demonstrated that some encounters are desirable for most wilderness users. For example, for most users one or two encounters are preferred over no encounters. Second, Shelby and Nielsen (1975), studying users of the Colorado River in the Grand Canyon, showed that some measures of satisfaction (trip quality) are unrelated to actual encounter levels in some situations. This finding has also been shown by Greenleaf and others (1984) in the White Mountains of New Hampshire. Third, Badger (1975) found that environmental damage and inappropriate behaviors are much more disturbing to users than encounters with others.

This third finding was extended by Harris (1978) in his study of crowding and satisfaction in the Rawah Wilderness. His findings suggested that several factors regarding the behavior of others have a greater effect on satisfaction than do encounters, even encounters with large groups or groups on horseback. From this we might conclude that the relationship between encounters and satisfaction is not linear. Encounters are not the sole, nor often the most important, factor in determining the sociological carrying capacity, a point very clearly made by Lee (1977). In fact, in one case Manning and Ciali (1980) showed that there is no relationship between reported increases in number of users and overall satisfaction rating. If encounters are important, then, their importance must vary with the location of encounter, the style of activity, the type of group encountered, and the saliency of encounters (Stankey and McCool 1984).

From research by Stankey (1980) we also learn that tolerance for encounters varies among wilderness areas. He compared the heavily used Desolation Wilderness with the more lightly used Spanish Peaks Primitive Area and found that Desolation users were more tolerant of higher levels of encounters; their satisfaction with their experience was maintained at higher levels of encounter. Greenleaf and others (1984) found a similar phenomenon in New Hampshire. Thus, while wilderness users are similar in their attitudes toward many things (Hendee and others 1968; Stankey 1971, 1973, 1980), they are not necessarily similar in their attitudes toward appropriate or tolerable encounter levels.

This research on encounters was designed to explore a major factor of sociological carrying capacity. We have learned from it a lot about both what people say and do in wilderness. But, by itself, it relates to only part of the carrying capacity question because it ignores wilderness resources.

Ecological Carrying Capacity.—We also have learned about ecological (resource-focused) carrying capacity in wilderness. Much of the work in this area, like the work on social carrying capacity, has focused on problems and potential problems rather than solutions, but recently there has been some work on solutions.

Frissell and Duncan (1965) clearly showed how campsites in the Boundary Waters Canoe Area were becoming denuded of vegetation and that erosion, soil compaction, and root exposure were serious problems on many sites. These problems, especially vegetation reduction, occurred fairly rapidly and with only light use. Merriam and Smith (1974) found that most ground cover and soil impact occurred during the first two seasons of use for Boundary Waters Canoe Area campsites.

Trail impacts similarly are most related to the first users; subsequent users usually follow established paths and cause erosion once the first users denude the trail (Helgath 1975). On Maine islands, however, even though ground cover vegetation was removed by trampling, there was little measurable trail formation, erosion, or soil compaction (Leonard and others 1985). As one might expect, there are differential effects by hikers and horseback users, with hikers generally less damaging. Research also has focused on effects of use on water quality with the general finding that, even in high-use areas, pollution from human sources is not a significant problem (Aukerman and Springer 1976; Werner and others 1985).

In the last few years Cole (1981, 1982, 1983) has reported research that describes both the type and extent of vegetation and soil impacts and suggests what might be done about them. One of his conclusions is that dispersal of use may not be a feasible way to reduce problems; in fact, he says more problems are created. Since most damage occurs from a small amount of use, dispersal simply compounds the problem. He recommends confining the impact to as small an area as feasible and living with the resulting site impact. Another conclusion from his work is that many campsite closures are not very effective in rehabilitating campsites because of slow rates of natural recovery, poor compliance by users, and failure to actively assist revegetation. Techniques such as soil scarification, seeding, and transplanting can positively affect recovery (Cole and Schreiner 1981), but, even with increased recovery, another problem was noted at the Big Creek Lake site (Montana): new campsites were created near the closed sites, effectively expanding the area of impact (Cole and Ranz 1983). While closures with revegetation assistance might improve isolated areas over time, one must consider the possibility of negative effects from the closures, especially the expansion of disturbed area. At Big Creek Lake, for example, closure of campsites caused the disturbed area to increase by 50 percent. Cole's results characterize what might be likely in many Western wilderness areas where the summers are relatively dry. Experience in parts of the East, however, suggests that rehabilitation of some sites might be more successful. For example, Leonard and others (1985) found on Hurricane Island, ME, that most species, given a 1-year recovery period, were able to withstand low levels of trampling stress. Ketchledge and others (1985) found that it was possible to reestablish alpine vegetation on the summits of the high peaks in the Adirondacks.

Moving Toward a Management Framework.—From these and other studies of social and biological aspects of carrying capacity we have learned about managing users and the resource. Such studies, however, could have been done without the concept of carrying capacity. One could simply have looked at satisfaction or effects on the resource and not tried to cast such effects in a broader context. This broader context seemed needed, however, to provide an organization and structure for wilderness management that would help managers ask questions about the multifaceted aspects of wilderness use and management. The search was for a holistic management framework to tie the pieces together, especially in the face of increasing use, resource impacts, and complaints about crowding and the reduction of the "wilderness experience."

While researchers recognized both the fallacy of deriving a single carrying capacity value (Lucas 1964b) and that there were problems in the direct transfer of carrying capacity concepts to management (Burch 1981; Wagar 1974), the ideas spawned from discussions of capacities and how they might be identified led to modeling the greater management system (Brown 1977a; Heberlein 1977; Stankey 1972). Stankey's model specified the kinds of information necessary to arrive at carrying capacity and the kinds of management responses to ensure use and impact within carrying capacity (fig. 1). Brown's model took a somewhat different focus and pointed out the place of carrying capacity determination within the major management decisions that must be made to arrive at a sound management program (fig. 2). Heberlein's model specified the process of arriving at a carrying capacity, and in so doing identified the role of management objectives, visitor assessment, and normative assessment in the management process. He clearly pointed out that satisfaction is not the sole criterion for establishing social carrying capacity. Specifying management objectives, examining user behavior, assessing user perceptions and preferences, and uncovering the norms that users express regarding use levels and encounters are each necessary in determining social carrying capacity.

Work on clarifying carrying capacity and its relationship to planning and management has continued, with notable achievements by Leonard and others (1977), Shelby and Heberlein (1986), and Graefe and others (1985). Leonard and others (1977), in developing a design capacity system, focused on many of the issues noted by Brown (1977b) and Heberlein (1977). They developed a system of assessing capacities that focused on future usage, facilities, and maintenance as factors that managers could control. Their contribution is an emphasis on designing for capacity rather than accepting carrying capacity as given. Shelby and Heberlein (1984, 1986) show the normative nature of carrying capacity analysis and the relationships among use, management, and impact parameters. Graefe and others (1985) cast their formulation into a management planning framework similar to the Recreation and Wilderness Opportunity Spectra and Limits of Acceptable Change frameworks described in other sections of this paper.

Estimating Carrying Capacity.—Attempts to actually estimate a carrying capacity have been few, though use limits have been imposed by management. Greene's (1976) study in the Rawah Wilderness, however, did illustrate what might be done.

Using the decision model described by Brown (1977a, 1977b) and Brown and others (1976), Greene demonstrated how user preference, resource capability, administrative, and current use information could be used in developing management objectives that, when combined with the physical structure of an area, would be the basis for deriving carrying capacity. Here are the general steps he followed (Greene 1976, p. 37-38).

1. Formulation of management objectives by weighing information concerning people's preferences, resource capabilities, institutional directives, and the existing situation.
2. Inventory of wilderness area's physical system structure—the physical capacity.
3. Using the physical capacity as a base (which includes information concerning user facilities and the area's physiographic character) determine what areas are acceptable for recreational use by overlaying the social and biological management standards.

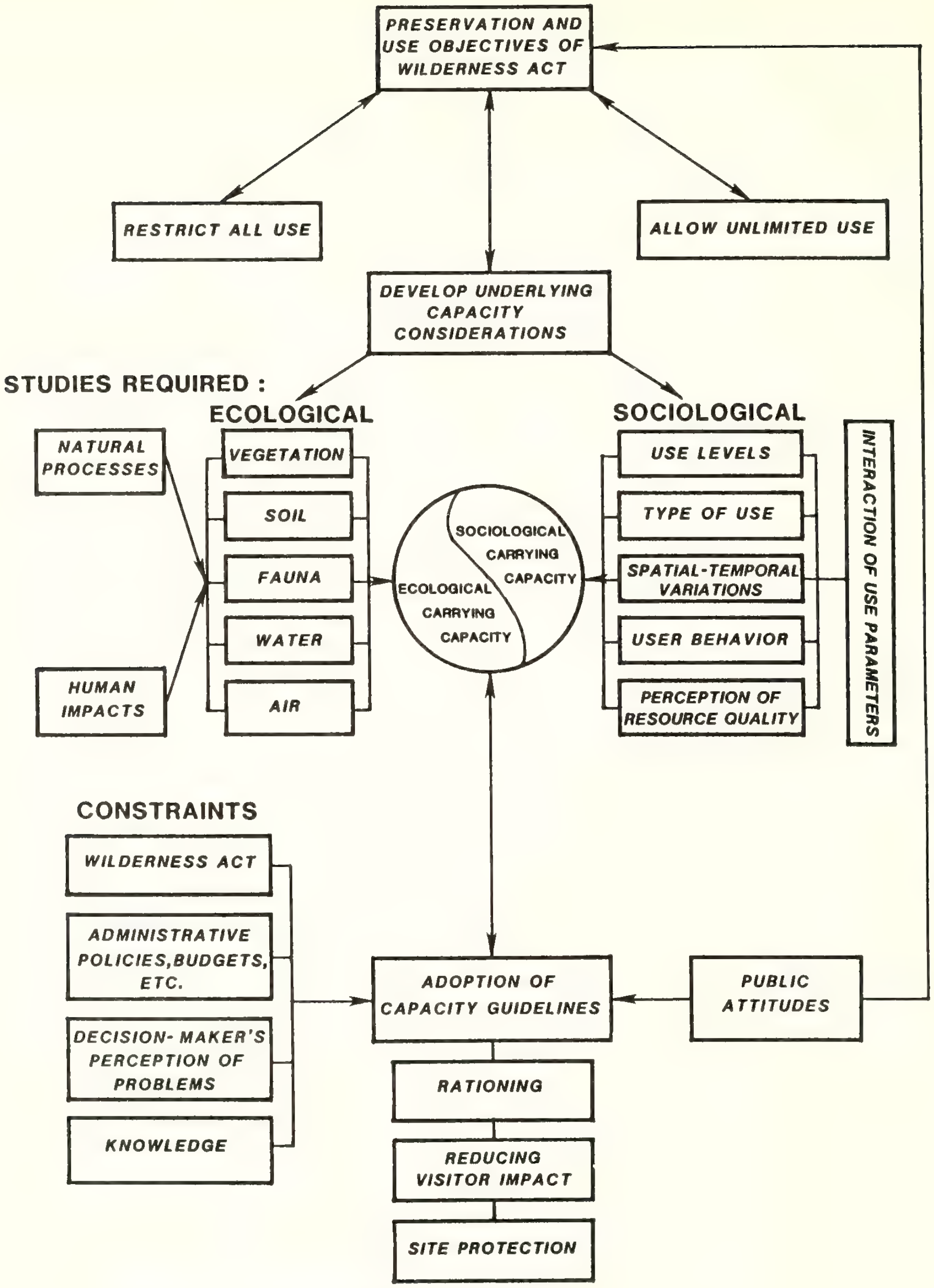

PRESERVATION AND USE OBJECTIVES OF WILDERNESS ACT
RESTRICT ALL USE
ALLOW UNLIMITED USE
DEVELOP UNDERLYING CAPACITY CONSIDERATIONS
STUDIES REQUIRED :
ECOLOGICAL
SOCIOLOGICAL
NATURAL PROCESSES
HUMAN IMPACTS
VEGETATION
SOIL
FAUNA
WATER
AIR
SOCIOLOGICAL CARRYING CAPACITY
ECOLOGICAL CARRYING CAPACITY
USE LEVELS
TYPE OF USE
SPATIAL-TEMPORAL VARIATIONS
USER BEHAVIOR
PERCEPTION OF RESOURCE QUALITY
INTERACTION OF USE PARAMETERS
CONSTRAINTS
WILDERNESS ACT
ADMINISTRATIVE POLICIES, BUDGETS, ETC.
DECISION- MAKER'S PERCEPTION OF PROBLEMS
KNOWLEDGE
ADOPTION OF CAPACITY GUIDELINES
PUBLIC ATTITUDES
RATIONING
REDUCING VISITOR IMPACT
SITE PROTECTION

Figure 1.—Stankey carrying capacity model. Source: Stankey (1972).

4. Calculate carrying capacity by estimating the number of people or parties that may use these "acceptable" areas for recreation at any one given time.

This process was applied to the 27,000-acre Rawah Wilderness near Fort Collins, CO. Two management objectives, one specifying acceptable social conditions and the other specifying acceptable physical-biological conditions, were drafted. The resources were mapped noting vegetative and soil conditions and campsite characteristics (especially visibility of other campsites). In this example, campsites were considered the critical determinant for carrying capacity. Thus, using the management objectives and the physical inventory of campsites, carrying capacity was calculated. Greene (p. 56) indicated, "This is done by using the physical capacity data as a base, and then determining which sites meet the biological and social standards specified in the management objectives." He also made the point that "judgment plays an important role when making these initial selections, and modifications in the number of available sites may be necessary if it is found that there are too many parties at a lake or if there is room for more parties without exceeding the standards" (p. 57). The result of his analysis is in table 1.

One should note that these capacity limits are specific to the management objectives articulated and to the management conditions that existed at the time of Greene's study.

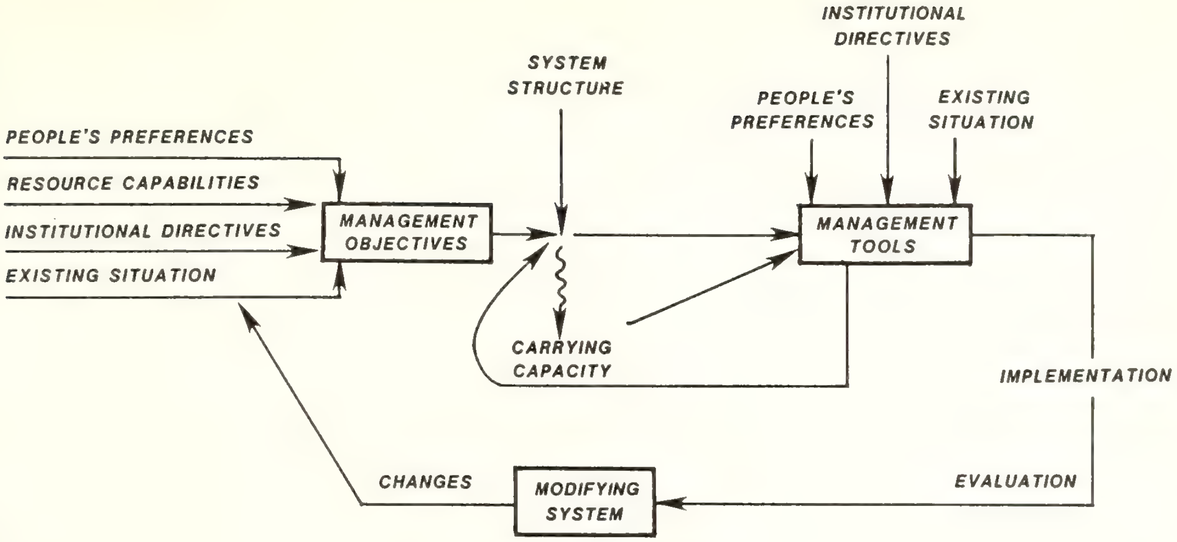


Figure 2.—Decisions with their inputs and outputs for a carrying capacity-based management system. Source: Brown (1977b).

Table 1.—Number of campsites conforming to management objectives that are available for different sized parties[1]

Sector of Rawah	Number of available campsites[2]		
	1-2 hikers	3-5 hikers	6+ hikers
1	2	3	1
2	29	12	1
3	55	26	15
4	25	9	9

[1] Source: Greene (1976, p. 64).

[2] All sites can be used by parties of one or two hikers, only sites in columns 2 and 3 can be used by parties of three to five hikers, and only sites in column 3 can be used by parties of six or more hikers.

He noted that other factors, such as seasonal considerations and different management practices, would result in different capacities. This is consistent with the Leonard and others (1977) notion of design capacities. Greene (p. 69) also cautioned that "the process of calculating carrying capacity is a means to the end of protecting a most precious, irreplaceable resource, and a most precious, irreplaceable experience." Calculating carrying capacity is not the end; it is the generation of one bit of information that might be useful in making subsequent management decisions.

Calculating carrying capacity is especially useful because it demands a holistic look at users, the resource, and management. It requires a model of the wilderness management system and thus proposes a process that requires the manager to focus on a multiplicity of relevant management questions. The research on carrying capacity has been largely a search for a holistic management framework. As we shall observe, it has helped lead to other useful concepts for planning and managing use of wilderness areas. It has helped us expand our focus beyond the "how much is too much" notion of carrying capacity to broader planning, management, and impact questions.

Recreation and Wilderness Opportunity Spectra

Some of the research on carrying capacity and the models of management suggested by Brown, Heberlein, Leonard, Lucas, and Stankey focuses attention on management objectives that specify the kinds of preservation and recreation use opportunities to be provided by management. This attention evolved to incorporate concepts of Recreation and Wilderness Opportunity Spectra in wilderness management.

Adapting the idea of a Recreation Opportunity Spectrum (ROS) to an operational planning and management framework has been useful for fitting recreation into multiple-use land management, including management of recreation in wilderness (Buist and Hoots 1982). The ROS is a framework for characterizing resource and visitor management aspects of the recreation phenomenon, especially characterizing the type, quantity, and quality of recreation opportunities.

As a concept for management, the ROS has been around for some time. The notion (though not necessarily the label) occurs in the writings of Marshall (1937), J. V. K. Wagar (1951), Burch (1964), Lucas (1964c), and J. A. Wagar (1966) among others. What has been suggested is that a diversity of recreation opportunities is needed to satisfy the desires of a heterogeneous public.

In the late 1970's, management need and research results came together in support of developing an operational ROS planning framework. To integrate recreation into land management planning under the National Forest Management Act (PL 94-588) and the Federal Land Policy and Management Act (PL 94-579) required something different than what we were then doing and ROS was proposed as a solution (Brown and others 1978; Driver and Brown 1978). At the same time, it was observed that management often changed recreation settings without a clear recognition of the consequences, and ROS was proposed as a solution to this problem (Clark and Stankey 1979). The outcome of these realizations was development of an operational ROS planning and management framework (Stankey and Brown 1981) that was adopted nationally by both the Forest Service and the U.S. Department of the Interior, Bureau of Land Management (Buist and Hoots 1982).

Research supporting development of an ROS was extensive. Burch's (1964) examination of collective aspects of recreation behavior, Lucas' (1964c) study of perception and use of the Boundary Waters Canoe Area, and Shafer's (1969) confirmation that the average camper does not exist all point to existence of recreational diversity. Studies of the desires for different types of experience by hunters (Potter and others 1973), anglers (Driver and Knopf 1976), river runners (Schreyer and Nielsen 1978), and wilderness users (Brown and Haas 1980) indicate that a diversity of opportunity is needed within and between recreation activities. Research by Peterson (1974), Allen (1979), Harris (1978), and others has confirmed that attributes of the recreational setting vary in importance for different individuals. Finally, Brown and Ross (1982) and Manfredo and others (1983) have shown a linkage among recreation activities, settings, and desired experiences, thus helping to tie together the notion that what people do, who does it, where they do it, and what they desire to get from doing it are important in planning for recreation use.

ROS Process.—The ROS has provided a clear distinction of the products of recreation management, recreation opportunities, and a process for integrating these products into land management planning. Building on the realizations that recreationists seek opportunities to: (1) participate in certain activities; (2) recreate in certain settings; and (3) realize specific experiences, one task of the recreation planner and manager "...is to formulate various combinations of activity and setting opportunities to facilitate the widest possible achievement of desired experiences" (Stankey and Brown 1981, p. 65).

This task is facilitated by the planner: (1) estimating demand for specifically defined recreation opportunities, (2) conducting a resource capability analysis to estimate potential for supplying various recreation opportunities, (3) identifying which recreation opportunities are currently provided, (4) determining where and how different recreation opportunities can optimally be provided, (5) integrating recreation opportunity recommendations with recommendations for other resource outputs, (6) developing alternative plans for resource allocation, (7) developing recreation action and project plans that are consistent with the allocation chosen, and (8) implementing plans and monitoring and evaluating the success of the implementation.

For managers, the outputs of ROS planning are: (1) specific management objectives for tracts of land that suggest the kind of recreation opportunity to be provided on each tract, (2) standards indicating acceptable conditions of elements of the recreation setting for each recreation opportunity, and (3) guidance for selection of appropriate management tools to be employed in meeting the management objectives. These outputs can be incorporated into either written or mapped plans to indicate to the manager what should be done to ensure meeting the recreational needs of target user publics.

ROS in Wilderness.—In the context of wilderness management, at least three uses have been made of the ROS. First, ROS has been used to make a clear distinction between the activity of recreation and the wilderness resource. That is, it has been used to make it clear that these are two different phenomena and that the manager's consideration of each must consider their differences. For example, we find some managers identifying primitive and unconfined forms of recreation only within wilderness while recreationists do not make such a narrow identification. Also, some managers have argued that the only kind of recreation in wilderness is primitive and unconfined. The point that the ROS framework makes is that wilderness areas and recreation opportunities are different things. Both designated wilderness and nonwilderness (roadless) areas can provide primitive and unconfined recreation. Because of the politics of wilderness designation, use patterns, and other factors, many places in wilderness, such as the lower reaches of the Eagles Nest Wilderness, the Crater Lake zone of the Maroon Bells-Snowmass Wilderness, and parts of some Eastern wilderness, provide recreation opportunities that are not generally defined as primitive and unconfined.

Second, ROS has been used to indicate the types of recreation opportunities currently existing in different parts of wilderness areas and the types that should exist in the future. The general primitive and semiprimitive recreation opportunity classes of the Forest Service and Bureau of Land Management often have been subdivided to characterize more finely defined opportunities so that management prescriptions could be more narrowly written (Stankey and others 1985).

Third, ROS has been transformed into a Wilderness Opportunity Spectrum (Haas and Plisco 1979). This transformation of the ROS idea suggests that all aspects of wilderness management, including recreation, wildlife, water, fire, and scientific use, can be prescribed after considering the conditions of the wilderness that need to be maintained or enhanced to provide a variety of opportunities. In essence, the general structure of the ROS framework, definition of opportunities, identification of relevant indicators of opportunities, and specification of acceptable standards for those indicators have been extended to develop management prescriptions for wilderness and its many aspects. An example of this has been carried out in the Maroon Bells-Snowmass Wilderness in Colorado.

Limits of Acceptable Change

As we have seen, both Greene's (1976) carrying capacity-based identification of desired conditions of the social and physical-biological systems and the development of a Wilderness Opportunity Spectrum suggest that some conditions are and other conditions are not acceptable in wilderness. This theme was well articulated by Frissell and Stankey (1972, p. 173) when they asked, "What are the 'limits of acceptable change' beyond that variation expected in a natural system?" They went on to describe a model of the "limits of acceptable change" in wilderness ecology which, in its current form, has become a model for clarifying the issues and making carrying capacity operational.

For some people the focus on carrying capacity, which was described previously, led to asking the wrong questions. Too much seemed to be focused on generating use limits and then assuming that regulation of use would solve problems of impact. But, as Stankey and others (1984, p. 34) noted, there is not "...a clear and predictable relationship between use and impact." Since there are so many factors involved in the relationship between use and impact on both the resource and experience, rather than asking how many users we should have, attention has turned to asking what conditions we want to have. This question was inherent all along in the goals of wilderness management and the articulation of management objectives, but was not being clearly asked when we were searching for a numerical carrying capacity.

The fundamental idea behind the Limits of Acceptable Change (LAC) is straightforward (Frissell and Stankey 1972). When looking at environmental conditions we should ask: What change beyond the natural variation in rate and character of change is acceptable? At what point does human-caused change alter unacceptably the character of the ecological system? Similar questions can be asked about change from what is defined as the pristine wilderness experience. What is tolerable; what is intolerable? To implement the LAC framework one needs to identify the conditions that are acceptable and establish the range between acceptability and unacceptability as the LAC.

Stankey and others (1984, p. 34) indicated that this

> ...shift in focus from "how much use" to "how much change" carries with it two important implications. First, it directs attention from use level as the key management concern to the environmental and social conditions desired in wilderness.
>
> The second implication of the LAC management framework is that it clearly places the issue of capacity in a prescriptive as opposed to technical context.

In summary, Stankey and others (1985, p. 2) indicated that "...the process requires deciding what kind of wilderness conditions are acceptable, then prescribing actions to protect or achieve those conditions."

A nine-step process has been defined for implementing LAC as a management framework for wilderness (Stankey and others 1984, 1985). This process parallels the Forest Service land management planning process. The LAC process is:

1. Identifying area concerns and issues
2. Defining and describing wilderness opportunity classes
3. Selecting indicators of resource and social conditions
4. Inventorying resource and social conditions
5. Specifying standards for resource and social indicators
6. Identifying alternative opportunity class allocations
7. Identifying management actions for each alternative
8. Evaluating alternatives and selecting an alternative
9. Implementing actions and monitoring conditions.

Specific research focusing on this framework is just now getting under way; there is not yet a validation of the framework's usefulness for managing to ensure resource protection and delivery of opportunities. Nonetheless, Stankey and others (1985) were able to illustrate how the system could be implemented for the hypothetical "Imagination Peaks Wilderness." Their example provided a good illustration of the flexibility and use of the framework.

As described by Stankey and others (1985), the LAC management framework has several elements that are much more specific now than they were in the earlier discussions of carrying capacity. The first is using issues and concerns (demand side components) to drive the system. This makes clear what publics and managers see as important. Second is the idea of opportunity classes, which are an outgrowth of work on the Recreation Opportunity Spectrum (Brown and others 1978; Clark and Stankey 1979; Driver and Brown 1978; Stankey and Brown 1981). These classes define consistent conditions among the various use, resource, and management parameters involved in managing wilderness. Third is the selection of indicators of resource and social conditions. Since it would not be feasible to identify and monitor every possible condition, indicators are selected to represent the state of the wilderness system. Fourth is the designation of standards for acceptable conditions of the indicators. These standards define the LAC and are the measurable core of management objectives. Fifth, the LAC framework has been formulated to suggest continuous public involvement. Public involvement is part of all phases of deciding what we want and how we will obtain it.

This change from a carrying capacity focus to the Limits of Acceptable Change was not the result of a specific research study. Rather, it was the result of an evolutionary process of learning more about the recreation phenomenon, about management, and about carrying capacity. The ROS development noted previously was certainly a contributor to this evolution, as was the resource impact work of Cole (1982) and the manager study by Washburne and Cole (1983). As managers and researchers have tried to make the carrying capacity model operational, they have continued to seek a more complete management model; the LAC model fills that need. It is more in tune with the times when questions are asked about the quality of the resource and the experience and when users demand a greater say in management decisions. It also is a framework that fits well with the rules and regulations for implementing the National Forest Management Act. LAC is a model that more completely satisfies the search for a holistic management framework.

Experience-Based Recreation Management

The change in management and research focus from regulation of numbers of users to conditions of the resource and experience has led to a different strategy for recreation management, labeled "experience-based recreation management" (Driver and Rosenthal 1982; Manfredo and others 1983). This strategy implies that the outcomes of recreation engagement in specific places are important. Furthermore, it implies that there is a relationship between what people do, the place where they do it, and what they get out of doing it (Driver and Brown 1978). If this is valid, then conditions of the resource and experience are important for satisfaction of recreationists. Such notions are consistent with guiding premises laid out by Wagar (1966) for recreation management and by Lucas (1973) for wilderness management. For example, Wagar said:

1. . . . the sole purpose of all land management is to provide benefits for people (p. 9)
2. . . . recreation, like all other human behavior is motivated by needs (p. 10)
3. . . . the quality of recreation depends on how well it satisfies the needs that motivate it (p. 10).

Given these ideas, the prescription for management would be to provide quality recreational opportunities that facilitate the fulfillment of recreationist needs. Lucas' (1973) principles for managing wilderness (cited previously) lead to the same management prescription. Finally, looking at these implications from another perspective we find that they are consistent with behavioral definitions of recreation (Brown 1983; Driver and Tocher 1970). Driver and Tocher indicated that recreation is a type of human experience that is based on intrinsically rewarding voluntary engagements during nonobligated time. This definition emphasizes the rewards or outcomes of participation in recreational activities, and thus visualizes experience as the central feature of recreation. With this definition the condition of the experience must be a focus of management.

What is experience-based recreation management? Very simply, it is management of resources and people ". . . which will increase the probability that specified types of satisfying experiences can be realized" (Driver and Rosenthal 1982, p. 34). With this strategy, managers attempt to provide opportunities for recreation activities involving specific equipment and groups at specific places with given physical-biological, social, and managerial conditions. Managers still are concerned with recreation activities and with the conditions of the recreation setting, but their motivation is to facilitate desired experiences, and thus perceived benefits, for recreationists. In acting on these ideas managers may utilize the ROS and LAC processes, which themselves are based on notions of experience-based management.

Considerable research underlies this approach to management, much of it focusing on users of wilderness and other backcountry areas. We can illustrate some of the background research by focusing on studies done by a Colorado group from 1974 to 1979. Badger's (1975) study of use tolerance levels focused on questions of acceptable levels of interaction among Rawah Wilderness users. For example, what levels of interaction inhibit realization of satisfaction? Harris' (1978) study of crowding and its effect on user satisfaction in the Rawah Wilderness increased our understanding of the relationship between social conditions of the recreational setting and user satisfaction, especially indicating that negative behaviors have a more significant effect on satisfaction than does crowding. Brown and Haas (1980) illustrated that the wilderness clientele in the Rawah Wilderness was quite diverse. At least five different groups, based on experience outcome profiles, were represented in 1975.

A somewhat similar finding was noted by Manfredo and others (1980) in looking at anglers in the Eagles Nest, Rawah, and Weminuche Wildernesses. In general, the same types (based on outcomes) of anglers were observed in the three areas, but nonanglers varied among the areas. Another finding of this study was that both anglers and nonanglers preferred a variety of attributes of the wilderness setting. For example, anglers in the Weminuche placed a higher value on all the physical features of the setting than did either Eagles Nest or Rawah anglers. A series of studies of preferences for attributes of the setting were undertaken in the Boundary Waters Canoe Area, Eagles Nest, Maroon Bells-Snowmass, Rawah, and Weminuche Wildernesses, and Kings Canyon National Park (Allen 1979; Anderson and Brown 1984; Haas 1979; Ross 1980; Zuckert 1980). They identified physical-biological, social, and managerial conditions in these areas that either are important to user satisfaction or cause change in user behavior, thus also indicating an effect on user satisfaction.

Two other significant studies of this group were the experiments by Schomaker (1975) and Krumpe (1979; Krumpe and Brown 1982) to redistribute backcountry use in the Rawah Wilderness and Yellowstone National Park, respectively. Both studies focused on giving recreationists information about the recreational setting that was related to possible experience outcomes. In both cases positive results were found. Schomaker's hypothesis that behavioral intention to follow a particular route and actual behavior would be correlated at a lower level for those groups receiving his information package than for the control group was confirmed. Krumpe, using a decision tree format in his information package, was able to influence the route choice of over 20 percent of the recreationists.

One study was specifically undertaken to test some of the ideas inherent in the experience-based management strategy (Manfredo and others 1983). These authors set out to determine if: (1) there are definable groups of wilderness recreationists that differ on desired experiences, (2) setting preferences differ among recreationists desiring different experiences, and (3) activity participation differs among recreationists desiring different experiences. It was assumed that if these hypotheses were not rejected, the notion from various psychological theories (see Fishbein and Ajzen 1975 and Lawler 1973) that there is a relationship between expected outcomes and behaviors in particular places would be sustained and an empirical basis would exist for experience-based management. The conclusion was "results offer support for the concepts tested; three groups with different preferences for experiences were identified and were found to differ on the activity, setting, and management actions they prefer" (Manfredo and others 1983, p. 263).

No single study confirms the validity of the strategy of experience-based management. All of these studies noted above, plus many others in wilderness and nonwilderness areas, led to the formulation of the experience-based management idea. This idea is not fully operational, but implementation of ROS/WOS and LAC processes, which are consistent with the strategy of experience-based management, will accelerate the process. Then, as we begin to monitor management resulting from the strategy and observe how users behave in response to this management we will be able to evaluate its usefulness and validity.

CARRYING OUT WILDERNESS MANAGEMENT DECISIONS

The broad role of wilderness management, taking a cue from Wagar (1966), is to provide benefits for people. More narrowly we have considered the roles to be maintaining the wilderness resource and providing opportunities for specific uses such as scientific, ecological reserve, and primitive and unconfined forms of recreation. Within the recreation role, we consider the relevant roles to be regulating both the opportunities for recreation and the behaviors of recreationists (Brown 1985).

The major decisions involved in recreation management have been identified as: (1) choosing management objectives, (2) deciding acceptable conditions for each objective, (3) choosing management actions appropriate and effective for reaching the objectives, and (4) changing objectives when evaluation shows a need (Brown 1977a, 1977b, 1985; Brown and others 1976). The first three decisions fit into the process of management planning while the fourth suggests evaluation of actions taken in response to management plans. These decisions describe the role of management in the production of benefits from recreation (Brown 1984; Driver and Brown 1984; Driver and Rosenthal 1982). They suggest that the primary roles for management are producing recreation opportunities and providing information to influence user expectations and behaviors (Brown 1985; Driver and Brown 1978).

Previous sections of this paper summarized research leading to the development of the strategy of experience-based wilderness management. That a number of researchers agree some overall framework or approach must be defined reflects recognition of the complexity as well as importance of management decisions. While individual frameworks vary in how they approach wilderness management, there is increasing recognition that the purposes of management are to identify, maintain, enhance, or restore *acceptable and appropriate conditions* in wilderness settings. By considering the major decisions in recreation management, we can learn what is known about acceptable and appropriate conditions for wilderness and its use.

Management Objectives

The concept of management objectives is prominent in recreation literature. Carrying capacity, Recreation Opportunity Spectrum, Limits of Acceptable Change, and the experience-based management strategies all suggest a need for management objectives. This arises because planning *is* selecting purposes (goals or aims) and choosing means of attaining them (Banfield 1959). Objectives, being measurable and attainable specifications of goals (Young 1970), are specific ways of stating the purposes of management and are thus inherent in any planning process.

Good objectives are time-bounded, and characterized by being specific, output-oriented, quantifiable, and attainable (Schomaker 1984). Objectives are useful in a number of ways. For example, they can help managers determine if a specific technique has been effective in reducing a problem; they narrow the range of acceptable actions; and they provide a specific, attainable target for managers.

Essentially, objectives specify what we want. For example, if the goal is to provide adequate opportunity for primitive and unconfined recreation, the objective will specify what we mean by adequate opportunity. "Adequate" might mean providing 20,000 hectares of primitive and unconfined recreation opportunity; it might be providing 200 persons at one time (PAOT) capacity of this opportunity; or it might involve some other standard of adequacy.

In formulating and choosing management objectives, research information might prove useful. The kind of information obtained from studies such as those by Stankey (1971, 1973) and Brown and Haas (1980) dealing with expectations and desires of users could be important. Such information tells what users think is appropriate for resource and social conditions or for the outcomes to be realized from recreational activity. Research such as that by Helgath (1975) and Cole (1983) is relevant for describing the current condition of the resource so that the manager knows the base from which he is beginning. Studies of use and areas are important for describing baseline conditions, comparisons with other areas, and, when information is available, trends in use.

Acceptable Conditions

Deciding what are acceptable conditions of the resource and recreation engagement occurs essentially during the phases in LAC where indicators are chosen and standards specified (Stankey and others 1985). In the case of providing opportunities for primitive and unconfined recreation, these acceptable conditions further define what we mean by primitive and unconfined recreation. They will describe acceptable limits for resource change, user behavior, and management inputs.

A large amount of wilderness research focuses on questions of acceptable conditions for factors such as encounters between users, appropriate behaviors of users, noise levels, vegetation and soil change, water quality, and user facilities.

The research of Stankey (1971, 1973), Badger (1975), Greenleaf and others (1984), and Shelby and Colvin (1982) is illustrative of kinds of information that are useful for developing standards about interactions among user groups. Stankey, Badger, and Greenleaf and others questioned wilderness and backcountry users about desirable encounter levels at various places in wilderness; Badger also asked about tolerable levels. Shelby and Colvin asked respondents to indicate the highest number of tolerable encounters for users of the Rogue River. In all cases, users were not anxious to encounter many other groups, and in the case of wilderness areas, excessive encounters at campsites were not tolerable. Generally, Rogue River users had higher tolerance limits than the wilderness users studied.

Noise, as a special factor associated with wilderness use, has had limited study. For example, Dailey and Redman (1975) studied normal background levels and found that noise disturbance depends on intensity, frequency, intermittent reoccurrence, and connotation. For pristine, primitive, and portal situations they provided specific quantitative estimates of acceptable decibel levels so that they could prescribe satisfactory campsite spacing.

Resources have also been the focus of study. For example, Merriam and Smith (1974), Cole (1982), and Leonard and others (1985) have examined vegetation impacts. Helgath (1975), Merriam and Smith (1974), Leonard and Plumley (1979), and Cole (1982) have looked at soil impacts. Barton (1969), Aukerman and Springer (1976), and Werner and others (1985) have looked at water impacts.

A large number of studies have looked at the acceptability of management practices and facilities. For example, Echelberger and Moeller (1977) queried users about the amount and density of trails and the use of patrol rangers in the Cranberry Backcountry and found that both were acceptable. Womble and others (1978) found both toilets and shelters, and Bultena and Taves (1961) found both toilets and fireplaces to be acceptable to the users they questioned.

Lucas' (1985) study recorded changes in preference and attitude of users of Montana's Bob Marshall Wilderness between 1970 and 1982 and thus provided planners with information about how use, users, and attitudes toward development of the wilderness are changing. He found, for example, that support for high-standard trails grew significantly while support for toilets decreased and support for patrol rangers remained the same from 1970 to 1982. Some changes are undoubtedly due to experiences in the Bob Marshall while others are due to changes in clientele. A striking example of the second case deals with interpretive signs. Interpretive signs were opposed by 1970 users while a majority of 1982 users favored them. But in 1982 they still were opposed by experienced users while novices favored them.

Management Tools

Management tools are the means of meeting the conditions specified by management objectives and standards. They are constrained heavily by prior decisions, but nonetheless are influenced by the existing situation, institutional directives, and expectations and desires of wilderness users.

Several authors have described the array of wilderness management tools as being located on a continuum from "light-handed" to "heavy-handed," based on the degree to which they modify versus regulate visitor behavior and freedom (Gilbert and others 1972; Lime 1976; Lime and Stankey 1971; McCool 1976). Peterson and Lime (1979) proposed that management actions can be directed at the consequences of visitor behavior (such as rehabilitation or restoration of campsite conditions), regulating behavior directly (through group size limits, campsite assignments, use limit policies), or through an indirect approach that manipulates the factors influencing visitor decision making (information about use densities, for example). Nearly all authors who have written on this topic agree that in wilderness settings, indirect approaches such as information and education are preferable to direct "heavy-handed" regulatory methods (Hendee and others 1978; Lime 1976; Lime and Stankey 1971; Lucas 1982, 1983; Peterson and Lime 1979) that might result in more intrusions into the experience.

These researchers are supported by vocal outcries by many wilderness users and commentators against direct regulation of visitors. For example, Behan (1974) reacted strongly against the suggestion of mandatory wilderness use permits by Hendee and Lucas (1973) despite the probable usefulness of permits in wilderness management (Fazio and Gilbert 1974). Some authors have even proposed "no rescue" wilderness areas—places where there would be both no regulation on visitor behavior as well as no rescue of users in case of injury (McAvoy and Dustin 1981, 1983). While the merits of this extreme alternative have been debated (Allen 1981; Wagar 1981), the fact that the proposal has been seriously put forth indicates a major concern among users with the potential intrusiveness of wilderness management tools.

Table 2 displays the array of management actions listed by Lime (1976). He listed actions according to their "heavy-handedness." In spite of the substantial discussion of this issue by a variety of researchers and managers, no research to date has identified the degree of "heavy-handedness" of different management actions. Our expectation is that many people will agree about the amount of "heavy-handedness" at the ends of the continuum, but there will be considerable debate about techniques somewhere in the mid-range. This gap is especially cavernous given the numerous debatable statements about wilderness and management (see Wuerthner 1985) as well as the heavy reliance on the construct by researchers (see Lime 1976).

Research focusing on appropriate and effective management tools has been carried out for many years and has focused on three major areas: (1) the acceptability of various management actions; (2) use and effectiveness of information in changing wilderness behavior; and (3) development and discussion of use limit policies. The first item in this list is the subject of review elsewhere in this volume (Stankey and Schreyer), so we will not repeat that information here.

We will focus our attention on the contemporary issues of information and use limit policies for two different reasons. First, information is a technique that many wilderness managers employ. Washburne and Cole's (1983) study of managers indicated that nearly 60 percent use information programs to help minimize impacts, more frequently than any other management tool studied. Martin and Taylor (1981) also reported that managers frequently depend on brochures, maps, and signs to encourage minimum-impact behavior. Second, use limit policies, and

Table 2.—Types of recreation management methods

Method type	Goal	Management tool
Site management (Emphasis on site design, landscaping, and engineering)	Harden site	Install durable surfaces (native, nonnative, synthetic) Irrigate Fertilize Revegetate Convert to more hardy species Thin ground cover and overstory
	Channel use	Erect barriers (rocks, logs, posts, fences, guardrails) Construct paths, roads, trails, walkways, bridges, etc. Landscape (vegetation patterns)
	Develop facilities	Provide access to underused and/or unused areas Provide sanitation facilities Provide overnight accommodations Provide concessionaire facilities (camping, picnicking, boating, docks, and other platforms, playground equipment, etc.) Provide interpretive facilities
Direct regulation of use (Emphasis on regulation of behavior; individual choice restricted; high degree of control)	Increase policy enforcement	Impose fines Increase surveillance of area
	Zone use	Zone incompatible uses spatially (hiker-only zones, prohibit motor use, etc.) Zone uses over time Limit camping in some campsites to 1 night, or some other limit
	Restrict use intensity	Rotate use (open or close roads, access points, trails, campsites, etc.) Require reservations Assign campsites and/or travel routes to each camper group in backcountry Limit usage via access point Limit size of groups, number of horses, vehicles, etc. Limit camping to designated campsites only Limit length of stay in area (max./min.)
	Restrict activities	Restrict building campfires Restrict fishing or hunting
Indirect regulation of use (Emphasis on influencing or modifying behavior; individual retains freedom to choose; control less complete, more variation in use possible)	Alter physical facilities	Improve (or not) access roads, trails Improve (or not) campsites and other concentrated-use areas Improve (or not) fish or wildlife populations (stock, allow to die out, etc.)
	Inform users	Advertise specific attributes of the area Identify the range of recreation opportunities in surrounding area Educate users to basic concepts of ecology Advertise underused areas and general patterns of use
	Set eligibility requirements	Charge constant entrance fee Charge differential fees by trail, zone, season, etc. Require proof of ecological knowledge and recreational activity skills

Source: Lime (1976)

how they are implemented through allocation and rationing programs, are controversial actions, which in many primitive river recreational settings have resulted in lawsuits, political pressure, and civil disobedience (McCool and Ashor 1984; McCool and Utter 1981). While these techniques and associated actions (campsite assignments and permits regulating use) have been implemented in only a few wildernesses, there is considerable concern about them among the using public. They are probably the most "heavy-handed" of the tools managers are likely to employ because they directly regulate behavior by restricting access to scarce resources. While most wilderness managers now agree that such approaches should be avoided if at all possible, there will continue to be situations where use limits are necessary to protect or restore wilderness conditions.

Research on Information.—Information is an increasingly important wilderness management tool. A study conducted in California's Yosemite National Park illustrates the need to understand more about how visitors use information. Bear-human conflicts had been increasing for several years, and improper food storage was the cause of 70 percent of all such incidents in the Yosemite backcountry. The National Park Service embarked on an information program to change backcountry users' food storage techniques to reduce the attractiveness of campsites to bears. Cella and Keay (1979) reported that about 95 percent of the backcountry users received the special brochure on bears, which contained information on proper food storage. Despite the high percentage of visitors who had received bear brochures, and while 92 percent of the campers believed they were properly storing food, checks of actual storage techniques indicated that only 3 percent were using correct methods. These results document the need to understand more about how people obtain, process, interpret, evaluate, and use information in wilderness settings.

While it has been only in the fairly recent past that researchers have turned to examining information as a management tool, there is substantial recognition of its "light-handed" nature. "Information seems to be a highly desirable visitor-management technique. It is nonauthoritarian and can serve the visitors' desires. . ." (Lime and Lucas 1977, p. 21). Most importantly, it alters visitor behavior while preserving freedom of choice.

While understanding how visitors use information developed by wilderness managers is important in selecting media, developing the message and appeals, and designing an information program, it is effectiveness, or how such information influences behavior, that is the ultimate goal of such programs. Effectiveness of various communication techniques is the subject of a tremendous amount of research in American society. Businesses are concerned about the effectiveness of their advertisements, politicians want to know if they are swaying the voters, teachers desire changes in cognitive levels of their students, attorneys are interested in influencing a jury of the guilt or innocence of a defendant, and wilderness managers want to know if their investments in minimum-impact programs are cost effective relative to implementation and enforcement of regulations.

There appear to be two types of behavior changes of interest to wilderness managers. First, management often wants to shift use patterns within a wilderness. The objective may be to reduce the pressure on attractive areas or to lessen the number of encounters in heavily used areas. Second, management also is concerned about changing visitor behavior to forms having fewer impacts on the resource. Research has addressed both issues.

As mentioned earlier, wilderness managers rely heavily on information to reduce or mitigate impacts from recreational use. Yet we know little about what managers are communicating to visitors and how visitors perceive that information. Fazio's (1979) study of wilderness information brochures found that about 16 percent included historical subjects; 30 percent discussed sanitation or fire prevention; 73 percent addressed appropriate wilderness equipment, safety, and comfort; and about 60 percent discussed "wilderness manners." Learning more about the subjects managers communicate about and how they do it is an obvious research need.

What have we learned about the visitor's use and perception of information? Research specifically directed toward this question has been minimal. The studies that have been conducted address several themes: (1) sources of information about alternative wilderness opportunities; (2) use of information to distribute visitors within the area; and (3) use of information to encourage minimum-impact behavior. Because of the lack of cumulative research, the conclusions presented within each of these themes should be considered tentative and in need of additional supporting research.

Research on Information-Seeking Behavior.—

1. *Potential visitors seek out and use a variety of information when making decisions about wilderness recreation opportunities.* McLaughlin and others (1984) and Utter (1979) have shown that friends, relatives, and acquaintances are frequently the most influential sources of information about a recreation opportunity. Dowell and McCool (1983) reported that less than 30 percent of their respondents indicated contact with Forest Service offices prior to a wilderness visit. They also reported that 90 percent of the visitors considered accurate maps desirable forms of information; 71 percent considered guidebooks desirable. Maps were the most frequently cited sources of information used for selecting trailheads.

2. *Visitors prefer an optimal amount of information that is provided outside of wilderness boundaries.* Lime and Lucas (1977) suggested that visitors could be provided with too much information, information that could detract from the exploratory and adventurous character of wilderness opportunities. This point of view is reflected on occasion by wilderness visitors seeking places that are simply "blank spots on the map." Dowell and McCool (1983) reinforced this statement when they found that only 37 percent of the visitors desired explanatory signs within the wilderness, implying that off-site information is more acceptable than information within the wilderness. An exception is the finding of Lucas (1982) that indicated that a majority of present users of the Bob Marshall Wilderness in Montana favored interpretive signing.

Research on Use of Information To Distribute Visitors.—

1. *Information can be effective in distributing visitors within an area.* Early in the history of recreation research, Brown and Hunt (1969) demonstrated that information, in their case highway signs, could be effective in changing use patterns from one area to another. This result was confirmed by a study of canoeists in the Boundary Waters Canoe Area (Lime and Lucas 1977) and of backcountry hikers (Echelberger and others 1983). Lucas (1981) attempted to shift use patterns from heavily used trails to more lightly used ones through a brochure made available at the trailhead. The brochure showed the relative amount of use among several adjacent trails and drainages. His study did not demonstrate a significant effect in redistributing use. A similar study by Schomaker (1975) yielded the same results. He found that behavioral intentions were influenced by a message about crowding and use in the Rawah Wilderness, but that his message,

given at the trailhead, came too late for much change in behavior on the current trip.

This study was followed by a classic field experiment (Krumpe and Brown 1982) in Wyoming's Yellowstone National Park. As backcountry visitors entered a ranger station to secure their permit, they were randomly selected to receive either a treatment (a backcountry "trail selector" map) or no treatment at all. Over 20 percent of the visitors changed their planned travel route when given alternatives supplied through the selector. A similar study reported by Roggenbuck and Berrier (1981) showed that campers in a North Carolina wilderness changed from heavily used to lightly used travel and camping areas in response to information about alternative campsites.

The results of these studies have enhanced our understanding of the conditions that make use dispersal information effective as well as when this technique does not seem to work.

2. *To be effective, information on alternative trails and locations must reach the recreationists at an appropriate point in the decision making process.* The Lucas (1981) and Schomaker (1975) studies showed that information about alternative trails presented at the trailhead was too late. The Krumpe and Brown (1982) research was conducted at ranger stations; many backcountry visitors still were in a position to change their minds about which trail to hike. Similarly, at the trailhead, Roggenbuck and Berrier (1981) informed visitors about alternative campsites well before the final campsite was selected. The brochure used by Lime and Lucas (1977) was sent to potential visitors prior to the summer use season, when initial decisions were being formulated.

3. *To be effective, information on alternative trails and locations must include descriptions of a variety of characteristics.* Krumpe and Brown (1982) and Lime and Lucas (1977) credit part of the success of their work to the variety of information made available to visitors. Lucas (1981) felt that focusing information on use levels alone was inadequate, a point recently reinforced by his (1985) finding that Bob Marshall Wilderness visitors more frequently mention scenery than solitude as a reason for entering the wilderness, and that encounters with others do not necessarily impact satisfaction.

4. *Use of information varies by experience level and degree of specialization.* Recent research suggests that more-experienced visitors use information differently than less-experienced visitors (Huffman and Williams 1986). Generally, it appears that experienced visitors rely less on agency information and more on personal communication and previous experience in making decisions about travel routes. Williams and Huffman (1986) reported that specialized hikers used information to the same extent as nonspecialists, but they tended to seek more detail in the information they received.

Research on Use of Information To Encourage Minimum-Impact Behavior.—

1. *Increases in knowledge about recreation impacts are accompanied by changes in attitudes and behavior.* A variety of research has examined the effectiveness of differing treatments in environmental education efforts (Schwabb 1982-83; Weiss and Knudson 1980; Zimmerman and others 1978). These studies show that use of information in situations similar to wilderness settings can result in major shifts in knowledge levels and subsequent behavior.

Only recently have researchers begun examining the effectiveness of minimum-impact information programs. Robertson (1981) demonstrated that among the nine independent variables (age, gender, occupation, income, primitive camping experience, conservation group membership, education, attitude toward wilderness, and knowledge of recommended wilderness behavior) she studied, knowledge was the most important contributor to minimum-impact behavior. This suggests that if knowledge levels can be changed, impacts can be reduced.

Oye (1984) examined the effectiveness of a wilderness education program in bringing about cognitive as well as affective changes in sixth-grade students. Knowledge scores were significantly increased (as compared to a control group), but attitudes remained the same.

Dowell and McCool (1986) reported the effectiveness of three alternative modes (slide program, booklets, slides and booklets) of presenting a Forest Service-developed program to Boy Scouts, heavy users of wilderness resources in many regions. Cognitive levels and behavioral intentions for the three treatment groups were higher than for the control. Among the independent variables studied (wilderness skills knowledge, general wilderness knowledge, beliefs and attitudes), wilderness skills knowledge was correlated the highest with behavioral intentions.

2. *A variety of methods can be used to communicate minimum-impact behavior skills.* The Dowell and McCool (1986) study used three different modes (slides, booklet with discussion, combination of slides and booklet) of presenting the program using both a highly credible source (male Forest Service uniformed employee) and a source of presumed lower credibility (nonuniformed female). Unlike some other studies (see Fazio and Gilbert 1974), this study showed few differences among the treatments, essentially indicating that the form in which information is presented makes little difference. No differences attributed to source credibility were found either.

Oliver and others (1985) measured actual behavior in a developed campground following a variety of information treatments regarding minimum-impact behavior. While their study showed some variation among treatments, all were statistically effective.

This line of research tends to confirm the validity of the managers' reliance on information as a tool that can be used to address impact problems. Offsite, managers must contend with retention issues; onsite, managers may have to compete with alternative attention grabbers (users may not visit an area to learn minimim-impact behaviors). However, we need to know more about information and education programs, their design, application, and effectiveness. Lucas and others (1985, p. 185) stated:

> . . . more needs to be done to identify the *key information* that we supply to visitors, *how* to best convey this information, how to determine whether education *produces* the desired behavior, and finally, how to *evaluate* the performance of different educational approaches as well as other management strategies.

Use Limit Policies.—While carrying capacity was the strategy around which much research and management were oriented in the 1970's, many managers sought to implement this construct through use limit policies. As noted earlier, a fundamental problem with the way in which carrying capacity was popularly defined was its emphasis on numbers of people, rather than on the appropriate and acceptable conditions for wilderness settings. "How many is too many?" was the question that managers posed and that researchers tried to answer.

Consequently, a number of areas, principally primitive river recreation settings, established use limit policies in the 1970's (Utter 1979). Research in river settings was directed not only at understanding the needs and motives of visitors, but also at how they perceived the acceptability and necessity of use limit policies and how those policies were implemented through allocation and rationing techniques. Often, limiting use in river situations was also complicated by Western water law, definitions of navigability, the public rights doctrine, and political posturing by various interest groups (Simmons 1977; Utter 1979).

Initial definitions of the extent and complexity of the unresolved and perplexing issues associated with use limits were provided by Warren (1977) and Stankey (1977). It quickly became apparent that this was a management problem without precedent. Not only were legal doctrines involved, but fundamental constitutional rights and responsibilities frequently became the center of litigation. These types of problems anchored one end of the spectrum, while at the other end managers dealt with such basic questions as the design of the form for a permit, type of rationing system desired, deadlines, "duplicate" reservation requests, and campsite assignments. The complexity, level of detail, and legal-philosophical issues soon became an overwhelming quagmire for management. The problems were especially acute on whitewater rivers in western North America where managers had been quick to adopt some type of use limit policy (Schreyer 1977).

A number of researchers turned their attention to these questions. Stankey and Baden (1977) and Shelby and Danley (1979) identified a range of alternative rationing approaches as well as the conceptual issues involved in dealing with rationing and the various consequences of different techniques. Investigations concerning the acceptability of limiting use were reported by Stankey (1973, 1979, 1980), Lucas (1980, 1985), and Shelby and others (1982) in designated wilderness. A number of researchers, including Schreyer and others (1976), Schreyer and Nielson (1978), Utter (1979), and McLaughlin and others (1984), addressed the issue in primitive river recreation settings. This research has led to a number of conclusions about use limit policies and how they are implemented.

1. *Visitors accept a use limit policy if there is agreement that such a policy is necessary to protect wilderness conditions.* One of the consistent results researchers have found is that in a wide variety of settings visitors will accept a use limit policy. Generally, however, such acceptance is contingent on a clearly defined need to protect either the wilderness resource or the experience. Stankey and Schreyer (this volume) review the research on visitor acceptance in greater detail.

2. *Wilderness visitors generally prefer reservation and queueing rationing systems, while river floaters prefer lotteries.* Generally, wilderness users were found to be more reluctant to accept lotteries (Shelby and others 1982) as a rationing technique than river recreationists (McCool and Utter 1982). Pricing was unanimously found to be unacceptable. Reservations (Schomaker and Leatherberry 1983) and first-come-first-served systems were usually favored over other alternatives. One technique that several have advocated, rationing by merit, did not find much favor. Stankey (1972) and Schreyer and others (1976) found that perceptions of the acceptability of differing rationing techniques are often influenced by the motives for visiting the area.

3. *Implementing use limit policies is a complex process that requires clearly stated objectives concerning how use is to be allocated.* Establishing a use limit policy is only the first step in a tremendously complicated process (McCool and Utter 1981). Following its implementation, a number of decisions are forced on the manager, including the potential of allocating use between outfitted and nonoutfitted users (Buist 1981). Such details of implementing use limit policies have been addressed by several researchers. Shelby and Danley (1979) argued for explicit statement of the specific goal of an allocation system: equity, equality, efficiency, or need. Shelby (1981) presented the economic values involved in allocations to river outfitters. Cordell (1981) suggested that some system similar to the free market be permitted to reduce use levels. McCool and Utter (1981) presented a framework for decision making following implementation of a use limit policy. Shechter and Lucas (1978) developed a wilderness travel simulation model that would help managers identify the consequences of alternative use management policies.

It now appears that a use limit policy is a technique of last resort. As managers have gained experience, there appears to be a general dissatisfaction with the technique as a way of solving problems even though many of the day-to-day operating problems have been smoothed out. Use limit policies are derived ultimately from the "how many is too many?" perspective. Managers and researchers now understand that for a use limit policy to be effective in solving problems there must be a unique and unambiguous relationship between use level and impact (Shelby and Heberlein 1984). In complex, two-dimensional spaces covering large and varied terrain, such a relationship may be difficult to uncover or establish.

We have learned much from our research and experiments with use limit policies. First, these policies probably generate more complex problems than they solve, particularly in the way they are implemented. While there is support among the using public for limiting use if necessary to protect or restore wilderness conditions, there is less agreement about how to implement the policy. Second, the policy itself is not an effective management response to specific problems of impact, crowding, or conflict. If it is implemented it must be complemented by additional tools. Third, there is growing recognition, indeed even preference (Wuerthner 1985), for other approaches to solving the problem because these other approaches have fewer side effects.

Much of the research in this area has depended on preference data from wilderness visitors. However, it would seem desirable to expand and build on this foundation through simulation experiments. Simulations can help subjects more realistically identify and react to the consequences of alternative use limit policies and how they are implemented. Simulations also can help managers understand how a particular policy will work, who will be affected and how, and the costs involved in implementation.

Monitoring and Evaluation

The final major class of management decisions focuses on how well the prior decisions about management objectives, standards, and tools meet social goals for wilderness management. We ask, "How effective and relevant is the management system?"

Research evaluating implementation of standards, management tools, and wilderness plans is scarce, though some of the research cited above does help both in making decisions about selecting appropriate tools and in changing the management program in response to evaluation. Stankey and others (1983, 1985) discussed monitoring and evaluation in recreation and wilderness and Lee's work (1982; Lee and others 1983) in the Steens Mountain Area of Oregon gave user evaluation of standards used in designating various backcountry recreation zones. A note by Leonard and others (1980) gave guidelines for monitoring use of backcountry trails. Papers by Anderson (1977), Echelberger and others (1981), Marnell (1977), and others suggest how to count recreation users. Our conclusion regarding monitoring and evaluation research is that there is a lot that needs investigating. Use of processes such as those associated with the ROS, LAC, and experience-based management will help provide the grist for both good evaluation and research on evaluation needs and processes.

Wilderness research has been done with an eye toward each of these major management decisions—choosing objectives, selecting indicators and standards, choosing management tools, and evaluating and changing the management system when necessary. What has been done is by no means exhaustive, and we can learn considerably more about wilderness, its use, and its management.

FUTURE RESEARCH: IMPROVING THE EFFECTIVENESS OF WILDERNESS MANAGEMENT

As noted earlier, our knowledge concerning how wilderness visitors feel about management and their motives, expectations, and characteristics has increased considerably in the last 20 years. We have an enhanced appreciation of the relationships between types and levels of recreational uses, impacts on the resource, and the wilderness experience. We now have far greater understanding of concepts important to wilderness experiences, such as solitude. We are beginning to see how attributes of wilderness settings affect visitors and their experiences. The fact that nine lengthy state-of-knowledge papers (this volume) can be written on different dimensions of wilderness-related research indicates that a fundamental knowledge base has been established.

In response to issues of crowding, conflict, and impact, managers have developed a large array of potential management techniques. Wilderness research has helped in this task because of its applied orientation and through the relationships that have developed between many wilderness researchers and managers. These relationships strongly enhance the ability of managers to communicate information needs and lead to researchers producing results useful to managers.

Researchers, themselves, have developed a set of management tools and concepts. Researchers, responding to managers' problems of identifying a carrying capacity, developed the LAC and the design capacity notions. Researchers also developed the wilderness travel simulation model. We expect the wilderness research community to continue to play this important role. While not research in the sense of "experiments" and statistical analyses, these contributions are important to technology development, transfer, and application. Their contributions, and the effectiveness of their use, rely on continued close relationships between management and research.

Our knowledge concerning the usefulness of new management concepts is limited, however, by the inability to evaluate them following application. For example, the efforts to learn under what conditions campsites in wilderness are impacted, the amount of the impact, the biophysical elements impacted, and the rate of impact have produced the opportunity for managers to deal more effectively with this problem. This knowledge serves as a base for managers to develop techniques to reduce impacts. However, we really know very little about these management techniques in terms of their effectiveness in reducing the problem. When managers develop techniques to reduce impacts based on results from research, they are actually performing "experiments," but often because of funding problems, or simply because managers are not trained in experimental design, or are unaware of the principles of monitoring (Stankey and others 1983), the actual effect of these experiments may not be known. Research can help overcome problems of lack of followthrough or objective measurement.

Testing the Effectiveness of Various Management Techniques

Ideally, this type of research would follow accepted experimental design and sampling principles. The research reported by Oliver and others (1985) demonstrated how experimental design can enhance our understanding of the effectiveness of different management techniques. While this type of research will cost money (as all research does), it has distinct payoffs in terms of learning what techniques are effective and under what conditions. Likewise, we are likely to determine why certain techniques are not effective. The manager could then allocate seemingly ever-scarcer dollars to techniques that are effective in maintaining or restoring acceptable wilderness conditions.

We must be careful about conducting this research. Because of its "opportunistic" nature, there will be a tendency to avoid theoretical constructs, a criticism that has been levied at wilderness visitor research before (Lee 1977). As researchers, we have a responsibility to ensure that our efforts are cumulative. Brown and others (1973) warned about the "Recreation Research, So What?" paradigm. We suggest that some type of research program be outlined to provide for greater opportunity for cumulative, synergistic contributions.

This type of research also will require close cooperation between managers and researchers, and may require managers to assume some risk to assess unproved techniques. To some extent, this will require researchers to take a risk also, because a certain amount of this research may not be the type that leads to tenure and promotion decisions.

But what type of management techniques should be the subject of research? There has been no systematic nationwide problem analysis of wilderness management research needs to provide guidance in making recommendations. Washburne and Cole (1983) did provide some insights into what managers perceive to be problems, but they did not ask managers to identify either research or information needs. Thus, in addition to the need noted above, the following are our impressions of what needs to be done.

Investigate the Legitimacy of Information and Education Tools

We hope that researchers soon will begin looking more closely at education and information as specific management techniques. We suggest this because of the frequency with which managers depend on them (Washburne and Cole 1983) and because of the lack of attention they have received in the wilderness research literature. Several questions need to be addressed. First, are such techniques effective? Do they result in changes in visitor behavior, specifically with respect to minimizing per-person impacts? What techniques are most effective for a specific problem? For example, are slides or personal messages more effective? Do different groups require the message to be presented differently? How does a manager educate those groups that may be responsible for much of the impact but which are also difficult to reach through standard channels of communication? What factors affect the transfer of knowledge in this situation? Is there a monitoring system for measuring effectiveness that could be used by field-level managers on a periodic basis?

We suspect that addressing this issue is going to require much in the way of interdisciplinary design and cooperation. Ecologists will have to identify the nature of the problem and supply the "correct" behavior. Media specialists will need to translate this information into an appropriate message. We can learn much from education research in terms of message design and delivery. Social-psychology can tell us something about how people will use this information, the situational and social factors affecting internalization of it, and the relationships between such factors as media, source credibility, message content, and changes in cognitive levels and behavioral intentions. Some of this research and experimentation may actually be done in a laboratory, while other components will require field experimentation. All of it should be done within theoretical constructs that will tie the fragmented studies together.

Identify How to Manage Ecological Impacts of Recreation in Wilderness Settings

Another line of inquiry concerns managing biophysical impacts in wilderness settings. Cole's review (this volume) shows that we know much about the relationship between types and levels of use and impacts. Again, however, the effectiveness of managing those impacts is an issue that must be addressed if impacts indeed will be reduced. For example, Ranz (1979) found that closures of campsites to reduce impacts in one part of the Selway-Bitterroot were ignored by a large proportion of the visiting public, and eventually led to the development of new campsites, thereby increasing the area impacted while only modest ecological recovery was observed on the closed campsites. Two questions are suggested by this research. First, why did many visitors ignore the obviously signed closures? Second, are recovery rates fast enough to justify closures if additional campsites (impacted areas) are created? Again, the research will have to be interdisciplinary and done in different geographical areas to be effective.

A similar question deals with trail conditions. Lucas (1985) reported that trail conditions were a main problem perceived by visitors to the Bob Marshall Wilderness complex in 1982. Is this a concern in this area alone? A large proportion of the money available for wilderness management is spent on trail construction, relocation, and maintenance. Thus, research may provide many benefits by allowing this money to be spent more efficiently. Research questions may focus on relationships between use types and levels and amount of impact. Management actions may be limited; it seems that educating visitors about trail impacts may have little effect, except perhaps in reducing the frequency of shortcutting switchbacks and in changing travel methods to less impacting ones. Research, for example, could focus on identifying soil types resistant to trail uses and researchers could assist managers in applying remote sensing technology to trail location and design. Also, levels of site management and engineering acceptable in wilderness need to be determined.

Investigate the Appropriate Roles of Various Wilderness Management Tools

A major unanswered question, one that has not had any research, is the construct of a "light-handed - heavy-handed" continuum underlying the array of management actions. As we noted earlier, a number of authors have postulated that this construct does describe the continuum, but there has been no verification of this. Several questions need to be examined. First, do visitors perceive such a continuum? Second, where do different techniques lie on it? Third, what are the roles of the techniques identified along this continuum? Several assumptions have been made that regulations are heavy-handed, but is this how the visitor perceives regulation? Frost (1985), for example, has shown that in some situations visitors may perceive regulations as enhancing experiences, not detracting from them. Under what kinds of conditions does this occur? A fourth issue deals with the tradeoffs among different types of regulations and the benefits and costs to the experience. For example, limiting use in a wilderness may be perceived by visitors as beneficial if there are no regulations once they enter the area. Thus, the location of a technique on the continuum may shift. Under what conditions do such shifts occur?

Define the Wilderness Management Job and the Skills Needed to Competently Carry Out the Associated Duties

Wilderness management is a relatively new field. What does the job involve? What types of skills are required to be an effective and competent wilderness manager? Why are some managers more likely to adopt the results of research than others? Here we expect the "diffusion of innovation" literature from rural sociology to be helpful. Why are certain management concepts and techniques more likely to be adopted than others? For example, many wildernesses now have a natural fire management policy. However, the backcountry trail selector developed by Krumpe and Brown (1982) (which demonstrated effectiveness in dispersing users) has not been adopted by any managers. Why was one adopted but not the other?

Given the fundamental changes in our society that are now occurring (see Toffler 1980), research could help identify the implications for managers. We fear that because of the traditional values involved in wilderness preservation, some managers may be caught in a conflict between these values and the new technology available to help get the job done efficiently. The changes occurring in social structure and values may be difficult for some to adopt. For example, Toffler indicated that the public wants to be more involved in governmental decision making. Research can help by identifying new ways for the public to participate (Ashor 1985; McCool and Ashor 1984; Stokes 1984) and new ways for managers to use the input they provide.

Evaluate the Consequences of Use Dispersal Policies

We feel there is a great need to specifically research the consequences of "use dispersal" policies. On many occasions, we have been told the answer to impact, crowding, and conflict problems is to disperse use. Cole's findings (this volume) suggest that such a policy may have severe negative consequences for the biophysical setting in sensitive Western areas while Leonard and others' (1985) findings suggest dispersal might be good in areas of the East. We hypothesize that a use dispersal policy also may reduce opportunities for solitude in those regions of a wilderness presently receiving light use. Perhaps the present users of these regions seek them because of the opportunities for solitude. Dispersing use into these areas could thus reduce the solitude available. Because of the frequency with which this management technique is suggested, we feel that research needs to look at it carefully before irretrievable commitments are made. Tools such as simulation models (Shechter and Lucas 1978) can help researchers and managers in this task.

Evaluate Existing Management Systems and Frameworks and Facilitate Creation of New Systems When Necessary

Finally, we need to learn more about entire management systems and regimes. LAC has become popular among some managers, but it has been implemented in only one or two situations as of this writing. We need to examine the success of LAC in these situations, the obstacles presented, how they were overcome, how specific problems were identified and dealt with, and if LAC eventually did make a difference on the ground. This is an important and high-priority line of inquiry because LAC might become more frequently used in management planning for wilderness. A major part of LAC is its requirement for monitoring. Monitoring can be used to determine the effectiveness of the overall process as well as individual management techniques, and results of the monitoring need to be diffused through the wilderness management field so that the level of success or failure with the system can be established.

Evaluation of a management regime will be a difficult task, and it may require a panel of researchers and managers working together. We feel this is necessary because without formal evaluation, we may not know if the regime has been successful. The causes of the success or failure will need to be identified to improve the regime and to notify other managers of what to seek and what to avoid. Also, in evaluating what we are doing, we likely will discover other things that might be done and begin to create better management processes. Such discovery, however, will surely be advanced if the evaluation is done with a clear idea of what management is designed to do.

Clearly we have learned a great deal about wilderness management, but considerably more remains to be learned. Research and management together have only begun to learn about user behavior, resource impacts, and the effectiveness of managing to ensure an enduring wilderness and opportunities for high-quality primitive and unconfined forms of recreation. A challenge for the future will be to be as productive as we have been in the past 25 years in learning about managing wilderness and its users.

REFERENCES

Allen, Deborah J. Wilderness user preferences for psychological outcomes and setting attributes. Fort Collins, CO: Colorado State University; 1979. 123 p. Ph.D. dissertation.

Allen, Stewart. Comment: no-rescue wilderness—a risky proposition. Journal of Forestry. 79(3): 153-154; 1981.

Anderson, Dorothy H. Strategies for counting river recreation users. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 388-389.

Anderson, Dorothy H.; Brown, Perry J. The displacement process in recreation. Journal of Leisure Research. 16(1): 61-73; 1984.

Anderson, Dorothy H.; Manfredo, Michael J. Visitor preferences for management actions. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 314-319.

Ashor, Joseph L. Recreation management in the Bob Marshall Wilderness complex: an application of the Limits of Acceptable Change concept and transactive planning theory. Missoula, MT: University of Montana; 1985. 224 p. M.S. thesis.

Aukerman, Robert; Springer, William T. Effects of recreation on water quality in wildlands. Eisenhower Consortium Bulletin 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1976. 25 p.

Badger, Thomas J. Rawah Wilderness crowding tolerances and some management techniques: an aspect of social carrying capacity. Fort Collins, CO: Colorado State University; 1975. 83 p. M.S. thesis.

Banfield, Edward C. Ends and means in planning. International Social Science Journal. 11(3): 361-368; 1959.

Barton, Michael A. Water pollution in remote recreational areas. Journal of Soil and Water Conservation. 24(4): 132-134; 1969.

Behan, R. W. Police state wilderness—a comment on mandatory wilderness permits. Journal of Forestry. 72(2): 98-99; 1974.

Brown, P. J. Defining the recreation experience. In: Rowe, Robert D.; Chestnut, Lauraine G., eds. Managing air quality and scenic resources at National Parks and wilderness areas. Boulder, CO: Westview Press; 1983: 3-12.

Brown, P. J.; Driver, B. L.; McConnell, C. The opportunity spectrum concept and behavioral information in outdoor recreation resource supply inventories: background and application. In: Integrated inventories of renewable natural resources: proceedings of the workshop; 1978 January 8-12; Tucson, AZ. General Technical Report RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1978: 73-84.

Brown, Perry J. Information needs for river recreation planning and management. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977a: 193-201.

Brown, Perry J. Whitewater rivers: social inputs to carrying capacity based decisions. In: Royer, Lawrence; Becker, William H.; Schreyer, Richard, eds. Managing Colorado River whitewater: the carrying capacity strategy—proceedings of a symposium; 1975 January 16-18; Moab, UT. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation, Institute for the Study of Outdoor Recreation and Tourism; 1977b: 92-121.

Brown, Perry J. Benefits of outdoor recreation and some ideas for valuing recreation opportunities. In: Peterson, George L.; Randall, Alan, eds. Valuation of wildland resource benefits. Boulder, CO: Westview Press; 1984: 209-220.

Brown, Perry J. Management objectives, recreation, and recreation management planning. In: Dustin, Daniel L., ed. The management of human behavior in outdoor recreation settings. San Diego, CA: San Diego State University; 1985: 1-10.

Brown, Perry J.; Driver, Beverly L.; Stankey, George H. Human behavioral science and recreation management. In: Proceedings of XVI IUFRO world congress—division 6; [conference dates unknown]; Oslo, Norway. [Place of publication unknown]: [Publisher unknown]; 1976: 53-63.

Brown, Perry J.; Dyer, Allen A.; Whaley, Ross S. Recreation research—so what? Journal of Leisure Research. 5(1): 16-24; 1973.

Brown, Perry J.; Haas, Glen E. Wilderness recreation experiences: the Rawah case. Journal of Leisure Research. 12(3): 229-241; 1980.

Brown, Perry J.; Hunt, John D. The influence of information signs on visitor distribution and use. Journal of Leisure Research. 1(1): 79-83; 1969.

Brown, Perry J.; Ross, David M. Using desired recreation experiences to predict setting preferences. In: Lime, David W., tech. coord. Forest and river recreation: research update. Miscellaneous Publication 18-1982. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1982: 105-110.

Buist, Leon J., ed. Recreation use allocation: proceedings of the national conference on allocation of recreation opportunities on public land between the outfitted and nonoutfitted publics; 1981 April 3-5; Reno, NV. Publication R-149. Reno, NV: University of Nevada Reno, Nevada Agricultural Experiment Station; 1981. 357 p.

Buist, Leon J.; Hoots, Thomas A. Recreation Opportunity Spectrum approach to resource planning. Journal of Forestry. 80(2): 84-86; 1982.

Bultena, Gordon L.; Taves, Marvin J. Changing wilderness images and forestry policy. Journal of Forestry. 59(3): 167-171; 1961.

Burch, William R., Jr. Two concepts for guiding recreation management decisions. Journal of Forestry. 62(10): 707-712; 1964.

Burch, William R., Jr. Wilderness—the life cycle and forest recreational choice. Journal of Forestry. 64(9): 606-610; 1966.

Burch, William R., Jr. The ecology of metaphor—spacing regularities for humans and other primates in urban and wildland habitats. Leisure Sciences. 4(3): 213-230; 1981.

Cella, W. B.; Keay, J. Annual bear management and incident report, Yosemite National Park. Survey of bear incidents, including survey of reasons and amounts of damage done; also a survey of bear information visitors received from the Park Service. El Portal, CA: U.S. Department of the Interior, National Park Service; 1979. 23 p.

Clark, Roger N.; Stankey, George H. The Recreation Opportunity Spectrum: a framework for planning, management, and research. General Technical Report PNW-98.

Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 32 p.

Cole, David N. Managing ecological impacts at wilderness campsites: an evaluation of techniques. Journal of Forestry. 79(2): 86-89; 1981.

Cole, David N. Wilderness campsite impacts: effect of amount of use. Research Paper INT-284. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 34 p.

Cole, David N. Monitoring the condition of wilderness campsites. Research Paper INT-302. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 10 p.

Cole, David N.; Ranz, Beth. Temporary campsite closures in the Selway-Bitterroot Wilderness. Journal of Forestry. 81(11): 729-732; 1983.

Cole, David N.; Schreiner, Edward G. S., compilers. Impacts of backcountry recreation: site management and rehabilitation—an annotated bibliography. General Technical Report INT-121. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 58 p.

Cordell, H. Ken. Pricing for allocating low-density recreational use between private and commercial users of natural areas. In: Buist, Leon J., ed. Recreation use allocation: proceedings of the national conference on allocation of recreation opportunities on public land between the outfitted and nonoutfitted publics; 1981 April 3-5; Reno, NV. Publication R-149. Reno, NV: University of Nevada Reno, Nevada Agricultural Experiment Station; 1981: 77-103.

Dailey, Tom; Redman, Dave. Guidelines for roadless area campsite spacing to minimize impact of human-related noises. General Technical Report PNW-35. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1975. 20 p.

Dana, Samuel Trask; Fairfax, Sally K. Forest and range policy: its development in the United States. New York: McGraw-Hill; 1981. 458 p.

Dowell, D. L.; McCool, Stephen F. Information: a management tool to help optimize wilderness users' satisfaction. In: McCool, Stephen F., ed. The Bob Marshall Wilderness visitor study. Missoula, MT: University of Montana, School of Forestry; 1983: 62-83.

Dowell, D. L.; McCool, Stephen F. Evaluation of a wilderness information dissemination program. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 494-500.

Driver, B. L.; Brown, P. J. Contributions of behavioral scientists to recreation resource management. In: Altman, Irwin; Wohlwill, Joachim F., eds. Behavior and the natural environment. New York: Plenum Press; 1984: 307-339.

Driver, B. L.; Brown, Perry J. The opportunity spectrum concept and behavioral information in outdoor recreation resource supply inventories: a rationale. In: Integrated inventories of renewable natural resources: proceedings of the workshop; 1978 January 8-12; Tucson, AZ. General Technical Report RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1978: 24-31.

Driver, B. L.; Knopf, R. C. Temporary escape: one product of sport fisheries management. Fisheries. 1(2): 21, 24-29; 1976.

Driver, B. L.; Rosenthal, D. H. Measuring and improving effectiveness of public outdoor recreation programs. Washington, DC: George Washington University, Department of Human Kinetics and Leisure Studies; 1982. 40 p.

Driver, B. L.; Tocher, S. Ross. Toward a behavioral interpretation of recreational engagements with implications for planning. In: Driver, B. L., ed. Elements of outdoor recreation planning: proceedings of a national short course; 1968 May 6-16; Ann Arbor, MI. [Place of publication unknown]: University Microfilms; 1970: 9-31.

Echelberger, H. E.; Leonard, R. E.; Plumley, H. J. Validation of trailside registration boxes. Journal of Soil and Water Conservation. 36(1): 53-54; 1981.

Echelberger, Herbert E.; Moeller, George H. Use and users of the Cranberry Backcountry in West Virginia: insights for eastern backcountry management. Research Paper NE-363. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p.

Echelberger, Herbert E.; Leonard, Raymond E.; Adler, Steven P. Designated-dispersed tentsites. Journal of Forestry. 81(2): 90-91, 105; 1983.

Fazio, J. R. Communicating with the wilderness user. Bulletin 29. Moscow, ID: University of Idaho, Forestry, Wildlife and Range Experiment Station; 1979. [Pages unknown].

Fazio, James R.; Gilbert, Douglas L. Mandatory wilderness permits: some indications of success. Journal of Forestry. 72(12): 753-756; 1974.

Fishbein, M.; Ajzen, I. Belief, attitude, intention and behavior: an introduction to theory and research. Reading, MA: Addison-Wesley Publishing Company; 1975. 572 p.

Frissell, Sidney S., Jr.; Duncan, Donald P. Campsite preference and deterioration in the Quetico-Superior canoe country. Journal of Forestry. 63(4): 256-260; 1965.

Frissell, Sidney S., Jr.; Stankey, George H. Wilderness environmental quality: search for social and ecological harmony. In: Proceedings of the 1972 national convention; 1972 October 1-5; Hot Springs, AR. Washington, DC: Society of American Foresters; 1972: 170-183.

Frome, Michael, ed. Issues in wilderness management. Boulder, CO: Westview Press; 1985. 252 p.

Frost, Jeffrey E. Visitor perceptions of management restrictions during Glacier Park's bald eagle concentration. Missoula, MT: University of Montana; 1985. 88 p. M.S. thesis.

Gilbert, C. Gorman; Peterson, George L.; Lime, David W Toward a model of travel behavior in the Boundary Waters Canoe Area. Environment and Behavior. 4(2): 131-157; 1972.

Graefe, Alan R.; Kuss, Fred R.; Vaske, Jerry J. Recreation impacts and carrying capacity: a visitor impact management framework. 1985. Unpublished report on file at: University of Maryland, Department of Recreation, College Park, MD.

Greene, Peter K. Calculating carrying capacity in wilderness areas. Fort Collins, CO: Colorado State University; 1976. 73 p. M.S. thesis.

Greenleaf, R. D.; Echelberger, H. E.; Leonard, R. E. Backpacker satisfaction, expectations and use levels in an Eastern forest setting. Journal of Park and Recreation Administration. 2(3): 49-56; 1984.

Haas, G. E.; Plisco, G. W. A co-op management—research demonstration project. In: Recreation planning and development: proceedings of the first annual national conference; 1979 April 18-21; Snowbird, UT. New York: American Society of Civil Engineers; 1979: 617-629. Vol. II.

Haas, Glenn E. User preferences for recreation experience opportunities and physical resource attributes in three Colorado wilderness areas. Fort Collins, CO: Colorado State University; 1979. 141 p. Ph.D. dissertation.

Harris, Charles C., Jr. Crowding in a wilderness setting: the influence of social interaction on user satisfaction. Fort Collins, CO: Colorado State University; 1978. 116 p. M.S. thesis.

Heberlein, Thomas H. Density, crowding, and satisfaction: sociological studies for determining carrying capacities. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 67-76.

Heinselman, M. L. Vegetation management in wilderness areas and primitive parks. Journal of Forestry. 63(6): 440-445; 1965.

Helgath, Sheila F. Trail deterioration in the Selway-Bitterroot Wilderness. Research Note INT-193. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 15 p.

Hendee, John C.; Catton, William R., Jr.; Marlow, Larry D.; Brockman, C. Frank. Wilderness users in the Pacific Northwest—their characteristics, values, and management preferences. Research Paper PNW-61. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968. 92 p.

Hendee, John C.; Harris, Robert W. Foresters' perception of wilderness-user attitudes and preferences. Journal of Forestry. 68(12): 759-762; 1970.

Hendee, John C.; Lucas, Robert C. Mandatory wilderness permits: a necessary management tool. Journal of Forestry. 71(4): 206-209; 1973.

Hendee, John C.; Lucas, Robert C.; Stankey, George H. Wilderness management. Miscellaneous Publication 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 381 p.

Huffman, Michael G.; Williams, Daniel R. Computer versus brochure information dissemination as a backcountry management tool. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 501-508.

James, George A.; Henley, Robert K. Sampling procedures for estimating mass and dispersed types of recreation use on large areas. Research Paper SE-31. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1968. 15 p.

Jubenville, Alan. A test of differences between wilderness recreation party leaders and party members. Journal of Leisure Research. 3(2): 116-119; 1971.

Ketchledge, E. H.; Leonard, R. E.; Richards, N. A.; Craul, P. F.; Eschner, A. R. Rehabilitation of alpine vegetation in the Adirondack Mountains of New York State. Research Paper NE-553. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 6 p.

Krumpe, Edwin E. Redistributing backcountry use by a behaviorally based communications device. Fort Collins, CO: Colorado State University; 1979. 156 p. Ph.D. dissertation.

Krumpe, Edwin E.; Brown, Perry J. Redistributing backcountry use through information related to recreation experiences. Journal of Forestry. 80(6): 360-362, 364; 1982.

Lawler, E. E., III. Motivation in work organizations. Monterey, CA: Brooks-Cole; 1973. 231 p.

Lee, Martha E. User perceptions of appropriate standards for Recreation Opportunity Spectrum criteria at Steens Mountain, Oregon. Corvallis, OR: Oregon State University; 1982. 96 p. M.S. thesis.

Lee, Martha E.; Brown, Perry J.; Manfredo, Michael J. User validation of planning criteria for inventorying and monitoring recreation resources. In: Bell, John F.; Atterbury, Toby, eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry; 1983: 318-322.

Lee, Robert G. Alone with others: the paradox of privacy in wilderness. Leisure Sciences. 1(1): 3-19; 1977.

Leonard, R. E.; Conkling, P. W.; McMahon, J. L. The response of plant species to low-level trampling stress on Hurricane Island, Maine. Research Note NE-327. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 6 p.

Leonard, R. E.; Echelberger, H. E.; Plumley, H. J.; Van Meter, L. W. Management guidelines for monitoring use on backcountry trails. Research Note NE-286. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1980. 20 p.

Leonard, R. E.; Echelberger, H. E.; Schnitzer, M. Use characteristics of the Great Gulf Wilderness. Research Paper NE-428. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1978. 9 p.

Leonard, R. E.; Plumley, H. J. The use of soils information for dispersed recreation planning. In: Ittner, Ruth; Potter, Dale R.; Agee, James K.; Anschell, Susie, eds. Conference proceedings—recreational impact on wildlands; 1978 October 27-29; Seattle, WA. No.

R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 50-63.

Leonard, R. E.; Plumley, H. J.; Holman, W. R. A design capacity system. In: National trails symposium proceedings; 1977 September 8-10; Lake Junaluska, NC. [Publisher name and location unknown]; 1977: 160-163.

Leopold, A. S.; Cain, S. A.; Cottam, C. M.; Gabrielson, I. W.; Kimball, T. L. Wildlife management in the National Parks. In: Trefethen, James B., ed. Transactions of the twenty-eighth North American wildlife and natural resources conference; 1963 March 4-6; Detroit, MI. Washington, DC: Wildlife Management Institute; 1963: 28-45.

Lime, David W. Principles of recreational carrying capacity. In: Proceedings of the Southern States recreation research applications workshop; 1975 September 15-18; Asheville, NC. General Technical Report SE-9. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1976: 122-134.

Lime, David W.; Lucas, Robert C. Good information improves the wilderness experience. Naturalist. 28(4): 18-21; 1977.

Lime, David W.; Stankey, George H. Carrying capacity: maintaining outdoor recreation quality. In: Larson, E. vH., ed. Recreation symposium proceedings; 1971 October 12-14; Syracuse, NY. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1971: 174-184.

Lucas, Robert C. Recreational use of the Quetico-Superior area. Research Paper LS-8. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1964a. 50 p.

Lucas, Robert C. The recreational capacity of the Quetico-Superior area. Research Paper LS-15. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station; 1964b. 34 p.

Lucas, Robert C. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Natural Resources Journal. 3(3): 394-411; 1964c.

Lucas, Robert C. The changing recreational use of the Boundary Waters Canoe Area. Research Note NC-42. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1967. 4 p.

Lucas, Robert C. Wilderness: a management framework. Journal of Soil and Water Conservation. 28(4): 150-154; 1973.

Lucas, Robert C. Use patterns and visitor characteristics, attitudes, and preferences in nine wilderness and other roadless areas. Research Paper INT-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 89 p.

Lucas, Robert C. Redistributing wilderness use through information supplied to visitors. Research Paper INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 15 p.

Lucas, Robert C. Recreation regulations—when are they needed? Journal of Forestry. 80(3): 148-151; 1982.

Lucas, Robert C. The role of regulations in recreation management. Western Wildlands. 9(2): 6-10; 1983.

Lucas, Robert C. Visitor characteristics, attitudes, and use patterns in the Bob Marshall Wilderness complex, 1970-82. Research Paper INT-345. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 32 p.

Lucas, Robert C.; Cole, David N.; Stankey, George H. Research update: what we have learned about wilderness management. In: Frome, Michael, ed. Issues in wilderness management. Boulder, CO: Westview Press; 1985: 173-188.

Lucas, Robert C.; Priddle, George B. Environmental perception: a comparison of two wilderness areas. Association of American Geographers Annals. 54(3): 428-429; 1964. Abstract.

Lucas, Robert C.; Schreuder, Hans T.; James, George A. Wilderness use estimation: a pilot test of sampling procedures on the Mission Mountains Primitive Area. Research Paper INT-109. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971. 44 p.

Lucas, Robert C.; Shechter, Mordechai. A recreational visitor travel simulation model as an aid to management planning. Simulation and Games. 8(3): 375-384; 1977.

Macinko, George. Constructing the man-made wilderness. In: McCloskey, Maxine E., ed. Wilderness: the edge of knowledge: 11th biennial wilderness conference; 1969 March 14-15; San Francisco, CA. San Francisco, CA: Sierra Club; 1970: 237-245.

Manfredo, M. J.; Brown, P. J.; Haas, G. E. Fisherman values in wilderness. In: Proceedings—Western Association of Fish and Wildlife Agencies Workshop. 52: 276-297; 1980.

Manfredo, Michael J.; Driver, B. L.; Brown, Perry J. A test of concepts inherent in experience based setting management for outdoor recreation areas. Journal of Leisure Research. 15(3): 263-283; 1983.

Manning, Robert E.; Ciali, Charles P. Recreation density and user satisfaction: a further exploration of the satisfaction model. Journal of Leisure Research. 12(4): 329-345; 1980.

Marnell, Leo F. Methods for counting river recreation users. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 77-82.

Marshall, R. The universe of the wilderness is vanishing. Nature Magazine. 1937 April: 235-240.

Martin, B. N.; Taylor, D. T. Informing backcountry visitors: a catalog of techniques. Gorham, NH: Appalachian Mountain Club; 1981. [Pages unknown].

McAvoy, Leo H.; Dustin, Daniel L. The right to risk in wilderness. Journal of Forestry. 79(3): 150-152; 1981.

McAvoy, Leo H.; Dustin, Daniel L. In search of balance: a no-rescue wilderness proposal. Western Wildlands. 9(2): 2-5; 1983.

McCool, Stephen F. Strategies and techniques for managing dispersed recreation in National Parks. In: Proceedings of the 3d resources management conference;

1976 April 29-30; Fort Worth, TX. Albuquerque, NM: U.S. Department of the Interior, National Park Service, Southwest Region; 1976: 259-290.

McCool, Stephen F.; Ashor, Joseph L. Politics and rivers: creating effective citizen involvement in management decisions. In: Popadic, Joseph S.; Butterfield, Dorothy I.; Anderson, Dorothy H.; Popadic, Mary R., eds. 1984 national river recreation symposium; 1984 October 31-November 3; Baton Rouge, LA. Baton Rouge, LA: Louisiana State University; 1984: 136-151.

McCool, Stephen F.; Utter, Jack. A process for allocating public recreation resources. In: Buist, Leon J., ed. Recreation use allocation: proceedings of the national conference on allocation of recreation opportunities on public land between the outfitted and nonoutfitted publics; 1981 April 3-5; Reno, NV. Publication R-149. Reno, NV: University of Nevada Reno, Nevada Agricultural Experiment Station; 1981: 60-76.

McCool, Stephen F.; Utter, Jack. Recreation use lotteries: outcomes and preferences. Journal of Forestry. 80(1): 10-11, 29; 1982.

McLaughlin, W. J.; Krumpe, E. E.; Sanyal, N.; Weesner, M. W. The Flathead River study: management unit analysis. Moscow, ID: University of Idaho; 1984. 345 p.

Merriam, L. C., Jr. The Bob Marshall Wilderness area of Montana—some socio-economic considerations. Journal of Forestry. 62(11): 789-795; 1964.

Merriam, L. C., Jr.; Smith, C. K. Visitor impact on newly developed campsites in the Boundary Waters Canoe Area. Journal of Forestry. 72(10): 627-630; 1974.

Oliver, Susan S.; Roggenbuck, Joseph W.; Watson, Alan E. Education to reduce impacts in forest campgrounds. Journal of Forestry. 83(4): 234-236; 1985.

Oye, Garry A. Wilderness education: evaluation of a sixth grade approach. Missoula, MT: University of Montana; 1984. 44 p. M.S. thesis.

Peterson, George L. Evaluating the quality of the wilderness environment: congruence between perception and aspiration. Environment and Behavior. 6(2): 169-193; 1974.

Peterson, George L.; Lime, David W. Two sources of bias in the measurement of human response to the wilderness environment. Journal of Leisure Research. 5(2): 66-73; 1973.

Peterson, George L.; Lime, David W. People and their behavior: a challenge for recreation management. Journal of Forestry. 77(6): 343-346; 1979.

Potter, Dale R.; Hendee, John C.; Clark, Roger N. Hunting satisfaction: game, guns or nature? In: Hendee, John C.; Schoenfeld, Clay, eds. Human dimensions in wildlife programs: reports of recent investigations. Washington, DC: Wildlife Management Institute; 1973: 62-71.

Ranz, Beth. Closing wilderness campsites: visitor use problems and ecological recovery in the Selway-Bitterroot Wilderness, Montana. Missoula, MT: University of Montana; 1979. 125 p. M.S. thesis.

Robertson, Rachel D. An investigation of visitor behavior in wilderness areas. Iowa City, IA: University of Iowa; 1981. 174 p. Ph.D. dissertation.

Roggenbuck, Joseph W.; Berrier, Deborah L. Communications to disperse wilderness campers. Journal of Forestry. 79(5): 295-297; 1981.

Ross, David M. Wilderness use level expectations and perceptions: their importance and congruence. Fort Collins, CO: Colorado State University; 1980. 108 p. M.S. thesis.

Roth, Dennis M. The wilderness movement and the National Forests: 1964-1980. History Series FS-391. Washington, DC: U.S. Department of Agriculture, Forest Service; 1984. 70 p.

Royer, Lawrence; Becker, William H.; Schreyer, Richard, eds. Managing Colorado River whitewater: the carrying capacity strategy—proceedings of a symposium; 1975 January 16-18; Moab, UT. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation, Institute for the Study of Outdoor Recreation and Tourism; 1977. 169 p.

Schomaker, John H. Effect of selected information on dispersal of wilderness recreationists. Fort Collins, CO: Colorado State University; 1975. 95 p. Ph.D. dissertation.

Schomaker, John H. Writing quantifiable river recreation management objectives. In: Popadic, Joseph S.; Butterfield, Dorothy I.; Anderson, Dorothy H.; Popadic, Mary R., eds. 1984 national river recreation symposium proceedings; 1984 October 31-November 3; Baton Rouge, LA. Baton Rouge, LA: Louisiana State University; 1984: 249-253.

Schomaker, John H.; Leatherberry, Earl C. A test for inequity in nine recreation reservation systems. Journal of Soil and Water Conservation. 38(1): 52-56; 1983.

Schreyer, Richard. Restricting recreational use of wildlands: lessons from whitewater rivers. Western Wildlands. 4(2): 45-52; 1977.

Schreyer, Richard; Nielson, Martin L. Westwater and Desolation Canyons: whitewater river recreation study. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation, Institute for the Study of Outdoor Recreation and Tourism; 1978. 195 p.

Schreyer, Richard; Roggenbuck, Joseph W.; McCool, Stephen F.; Royer, Lawrence E.; Miller, Jay. The Dinosaur National Monument whitewater river recreation study. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation, Institute for the Study of Outdoor Recreation and Tourism; 1976. 165 p.

Schwabb, Karl E. Instructional methods: their use and effectiveness in environmental education. Journal of Environmental Education. 14(2): 8-12; 1982-83.

Shafer, Elwood L., Jr. The average camper who doesn't exist. Research Paper NE-142. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1969. 27 p.

Shechter, Mordechai; Lucas, Robert C. Simulation of recreational use for park and wilderness management. Baltimore: The Johns Hopkins University Press for Resources for the Future, Inc., Washington, DC; 1978. 220 p.

Shelby, Bo. Allocation issues identified in recreation research. In: Buist, Leon J., ed. Recreation use allocation: proceedings of the national conference on allocation of recreation opportunities on public land between the outfitted and nonoutfitted publics; 1981 April 3-5; Reno, NV. Publication R-149. Reno, NV: University of Nevada Reno, Nevada Agricultural Experiment Station; 1981: 35-50.

Shelby, Bo; Colvin, Rick. Encounter measures in carrying capacity research: actual, reported, and diary contacts. Journal of Leisure Research. 14(4): 350-360; 1982.

Shelby, Bo; Danley, Mark. Allocating river use. Final report to USDA Forest Service regarding "Private and Commercial Use Allocations for the Snake River in Hells Canyon." Research was conducted under Supplement No. 185 to Master Memorandum of Understanding between the School of Forestry, Oregon State University, and the Pacific Northwest Forest and Range Experiment Station. [Place of publication unknown]: [Publisher unknown]; 1979. 131 p.

Shelby, Bo; Danley, Mark S.; Gibbs, Kenneth C.; Petersen, Margaret E. Preferences of backpackers and river runners for allocation techniques. Journal of Forestry. 80(7): 416-419; 1982.

Shelby, Bo; Heberlein, Thomas A. A conceptual framework for carrying capacity determination. Leisure Sciences. 6(4): 433-451; 1984.

Shelby, Bo; Heberlein, Thomas A. Carrying capacity in recreation settings. Corvallis, OR: Oregon State University Press; 1986. 164 p.

Shelby, Bo; Nielsen, J. M. Use levels and user satisfaction in the Grand Canyon. Boulder, CO: Human Ecology Research Service, Inc.; 1975. 36 p.

Simmons, Robert M. Legal aspects of river recreation management in the West. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 32-37.

Snyder, A. P. Wilderness management—a growing challenge. Journal of Forestry. 64(7): 441-446; 1966.

Spurr, Stephen H. The value of wilderness to science. In: Leydet, Francois, ed. Tomorrow's wilderness. [The eighth biennial wilderness conference]; [Date and location of conference unknown]. San Francisco, CA: Sierra Club; 1963: 59-75.

Stankey, George H. The perception of wilderness recreation carrying capacity: a geographic study in natural resources management. East Lansing, MI: Michigan State University; 1971. 351 p. Ph.D. dissertation.

Stankey, George H. A strategy for the definition and management of wilderness quality. In: Krutilla, John V., ed. Natural environments: studies in theoretical and applied analysis. Baltimore: The Johns Hopkins University Press for Resources for the Future, Inc., Washington, DC; 1972: 88-144.

Stankey, George H. Visitor perception of wilderness recreation carrying capacity. Research Paper INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 61 p.

Stankey, George H. Rationing river recreation use. In: Proceedings: river recreation management and research symposium; 1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 397-401.

Stankey, George H. Use rationing in two southern California wildernesses. Journal of Forestry. 77(5): 347-349; 1979.

Stankey, George H. A comparison of carrying capacity perceptions among visitors to two wildernesses. Research Paper INT-242. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 34 p.

Stankey, George H.; Baden, John. Rationing wilderness use: methods, problems, and guidelines. Research Paper INT-192. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 20 p.

Stankey, George H.; Brown, P. J. A technique for recreation planning and management in tomorrow's forests. In: Proceedings of XVII IUFRO world congress—division 6; 1981 September 7-12; Kyoto, Japan. [Place of publication unknown]: [Publisher unknown]; 1981: 63-74.

Stankey, George H.; Brown, Perry J.; Clark, Roger N. Monitoring and evaluating changes and trends in recreation opportunity supply. In: Bell, John F.; Atterbury, Toby, eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry; 1983: 227-230.

Stankey, George H.; Cole, David N.; Lucas, Robert C.; Petersen, Margaret E.; Frissell, Sidney S. The Limits of Acceptable Change (LAC) system for wilderness planning. General Technical Report INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 37 p.

Stankey, George H.; McCool, Stephen F. Carrying capacity in recreational settings: evolution, appraisal, and application. Leisure Sciences. 6(4): 453-473; 1984.

Stankey, George H.; McCool, Stephen F.; Stokes, Gerald L. Limits of Acceptable Change: a new framework for managing the Bob Marshall Wilderness complex. Western Wildlands. 10(3): 33-37; 1984.

Stokes, Gerald L. Managing the Blackfoot River: a local approach. In: Popadic, Joseph S.; Butterfield, Dorothy I.; Anderson, Dorothy H.; Popadic, Mary R., eds. 1984 national river recreation symposium proceedings; 1984 October 31-November 3; Baton Rouge, LA. Baton Rouge, LA: Louisiana State University; 1984: 585-604.

Toffler, Alvin. The third wave. New York: Bantam Books; 1980. 438 p.

Utter, Jack G. Wild river recreation management: a case study of the use allocation issue. Missoula, MT: University of Montana; 1979. 305 p. Ph.D. dissertation.

Wagar, J. Alan. The carrying capacity of wildlands for recreation. Forest Science Monograph 7. Washington, DC: Society of American Foresters; 1964. 24 p.

Wagar, J. Alan. Quality in outdoor recreation. Trends. 3(3): 9-13; 1966.

Wagar, J. Alan. Recreational carrying capacity reconsidered. Journal of Forestry. 72(5): 274-278; 1974.

Wagar, J. Alan. Comment on "The right to risk in wilderness." Journal of Forestry. 79(3): 152-153; 1981.

Wagar, J. V. K. Some major principles in recreation land-use planning. Journal of Forestry. 49(6): 431-435; 1951.

Warren, Sam E. How to ration river floating use: the Middle Fork of the Salmon experience. In: Proceedings: river recreation management and research symposium;

1977 January 24-27; Minneapolis, MN. General Technical Report NC-28. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1977: 151-154.

Washburne, Randel F.; Cole, David N. Problems and practices in wilderness management: a survey of managers. Research Paper INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 56 p.

Weis, Charles N.; Knudson, Douglas M. Naturalists and the mass media: reaching beyond the parks. Journal of Environmental Education. 11(4): 41-44; 1980.

Wenger, Wiley D., Jr. A test of unmanned registration stations on wilderness trails: factors influencing effectiveness. Research Paper PNW-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1964. 48 p.

Wenger, Wiley D., Jr.; Gregersen, H. M. The effect of nonresponse on representativeness of wilderness-trail register information. Research Paper PNW-17. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1964. 20 p.

Werner, Robert G.; Leonard, Raymond E.; Crevelling, James O. Impact of backcountry recreationists on the water quality of an Adirondack lake. Research Note NE-326. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 4 p.

Williams, Daniel R.; Huffman, Michael G. Recreation specialization as a factor in backcountry trail choice. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 339-344.

Womble, Peter; Wolf, Wendy; Field, Donald. Hikers on the Chilkoot Trail: a descriptive report. In: Sociology Studies Program. Seattle, WA: University of Washington, Cooperative Park Studies Unit; 1978: [Pages unknown].

Wuerthner, George. Managing the wild back into the wilderness. Western Wildlands. 11(3): 20-24; 1985.

Young, R. C. Establishment of goals and definition of objectives. In: Driver, B. L., ed. Elements of outdoor recreation planning: proceedings of a national short course; 1968 May 6-16; Ann Arbor, MI. [Place of publication unknown]: University Microfilms; 1970: 261-272.

Zaslowsky, D. Managing the dream. Wilderness. 48: 27-33; 1984.

Zimmerman, D. E.; Scherer, D.; Larson, M. The use of conservation and environmental mass media by Pennsylvania educators. Journal of Environmental Education. 10(2): 43-48; 1978.

Zuckert, Judith A. Environmental and psychological determinants of campsite selection at a high Sierra lake. Fort Collins, CO: Colorado State University; 1980. 72 p. M.S. thesis.

AUTHORS

Perry J. Brown
Professor of Resource Recreation
Oregon State University
Corvallis, OR 97331

Stephen F. McCool
Professor of Wildland Recreation
University of Montana
Missoula, MT 59807

Michael J. Manfredo
Associate Professor of Resource Recreation
Oregon State University
Corvallis, OR 97331

Section 4. Future Directions

ENVIRONMENTAL PROTECTION AND PRESERVATION RESEARCH PRIORITIES

A. Alan Hill

It is indeed a pleasure to join with you today. I've looked forward to being with you since Glenn Haas visited me early last spring and outlined the important purposes of this conference.

I'm sure that if we polled this room we could come up with as many statements of the value of wilderness as there are people attending. One of my favorite thoughts about wilderness came from a cab driver in Washington, DC, a couple of weeks ago. This gentleman told me he knew all about wilderness because he's had a flat tire in Rock Creek Park!

Now I'll claim a little greater wilderness exposure than the man driving the cab. The point of my story, though, is that each individual values some kind of wilderness experience for his or her own personal set of reasons.

When I was a Scoutmaster, we took a trip to Oregon's Three Sisters to earn the "50 Miler" patch. I remember on a particularly trying day when one of the Scouts, who was concerned about protection of the area where we were camping, told me he remembered what Theodore Roosevelt said, "Walk softly and carry a big bed!"

During our family trips to wilderness areas in the Sierra, my boys learned to fish. My wife and I have developed an interest in wildflowers. And, most important, we've learned respect for the rare visit to camp by a representative of the Ursidae family.

Over this time, which spans nearly 25 years, we have seen the passage of the Wilderness Act and participated in discussions of the size, boundary, inclusions, and exclusions of many of the formally designated wildernesses. More accurately, we have seen the establishment and growth of the National Wilderness Preservation System, a system of preserves that now contains nearly 90 million acres. Let me underline the word "preservation."

President Reagan put it best last year when he said, "Generations hence, parents will take their children to these woods to show them how the land must have looked to the first Pilgrims and pioneers."

THE VITAL QUESTIONS

Now, the nation has had more than 20 years experience, and it is most important to focus on the vital questions for the years ahead. Those relate to issues of protection and management of these vital resources. It is quite appropriate for researchers to gather to compare findings and to communicate with all interested parties, including the people who carry out management programs.

I'd like to take the next few minutes to share some of the thoughts we at the Council on Environmental Quality have regarding wilderness—that is, on wilderness in the broader perspective of the national good, not merely the personal benefit we derive.

Last fall and winter, CEQ convened a set of four 2-day meetings of experts to focus on the need for long-term environmental research and development. We issued our final report on March 18, 1985. Basically, the panels focused on specific research areas. Those are:

- human health impacts and their mitigation;
- geochemical and hydrologic processes and their protection;
- environmental impacts and their mitigation; and finally,
- monitoring, assessment, and environmental management.

Our project was a cooperative effort of EPA, the National Science Foundation, the Department of Energy, the National Institute of Environmental Health Sciences, and the Nuclear Regulatory Commission. Copies of the report are available through CEQ.

While many of the recommendations go to issues well beyond those concerned with wilderness, there are many which will bear directly on the subject of this conference.

One underlying theme of this conference is "information"—information developed through research monitoring and the contribution and maintenance of accurate data bases. I am reminded of a story that appeared in the **Chicago Tribune**:

> Abraham Lincoln was vastly disturbed during the Civil War because he was so often denounced and criticized by people who pretended to be wise on a minimum diet of facts and information. They offered wisdom they did not possess. So, whimsically he told the story of a backwoods traveler lost in a terrific thunderstorm. The rider floundered thru the mud until his horse gave out. Then he stood alone in the middle of the road while lightning streaked and thunder roared around him. One crash seemed to shake the earth underneath, and it brought the traveler to his knees. He was not a praying man but he made a petition short and to the point: "O Lord, if it is all the same to you, give us a little more light and a little less noise."

The point is, we cannot give light or wisdom we do not have, and we do more damage than good when we speak with authority from a vacuum of knowledge and information.

LONG-TERM LOOK NEEDED

In order to remove that vacuum, we need to begin at the beginning—and that is with research—research which spans as great an amount of time and covers as many critical areas of concern to be useful and effective. We need to look at the long term.

Long-term environmental research and development (R&D) includes three kinds of activities: (1) anticipatory research, designed to identify potential environmental problems before they occur; (2) investigations of a continuing nature, such as ecological baseline studies, which may require a period of up to several decades to complete; and (3) fundamental research, the output of which may advance basic understanding of environment-related processes.

Scientists knowledgeable about health and environment recognize that human pressures placed upon natural resources, both living and nonliving, are more severe than previously suspected.

During the past 40 years a wide variety of new synthetic chemicals has been introduced, some of which appear to pose serious acute and chronic health effects. Of similar concern is evidence of potential damage to such important natural processes or properties as biogeochemical cycling or biologic diversity.

Ignorance about many scientific questions has resulted in acknowledged problems of environmental management, such as inappropriate regulation in the face of data uncertainties or heightened public anxieties. Long-term environmental and health research is needed to resolve scientific uncertainties, to establish baseline health and environmental parameters, to overcome lack of understanding of the short-term variations in natural systems, and to identify long-term trends and relate them to their causes.

For a variety of reasons, current incentives for private sector and governmental support of environmental and health R&D favor short-term approaches. Government agency research programs are generally designed to support mission goals of the agencies sponsoring them, resulting in relatively short-term research planning horizons that do not extend beyond immediate regulatory or programmatic requirements. Similarly, corporate research efforts frequently support near-term product development strategies and are necessarily reflective of annual (or shorter) profit and loss statements.

Current government and public concern over such environmental problems as acid deposition phenomena illustrates the fallacy in continued reliance on short-term research design. Although the potential environmental and health effects of acid particulates were pointed out years ago, relatively little research attention was devoted to following up on early studies noting these effects, and commitment of resources could not be justified on the basis of then-current regulatory strategies. Accordingly, long-term acid rain research programs were deferred; had they been undertaken a decade ago, they might by now have been yielding information and predictive models of use to current regulators and policymakers.

We believe there is need for a greater resource commitment to and better direction, coordination, and interdisciplinary integration of long-term environmental and health R&D. Improvements in environmental management will flow from better characterization of environmental phenomena, increased understanding of basic mechanisms, and the development of more meaningful measures of hazard or harm assessment. There clearly is a need for good long-term monitoring data and accompanying quality assurance to evaluate models used for understanding processes and environmental trends. Lack of validated monitoring time series data, based upon even crude health and environmental measures, has impeded the expansion of fundamental research programs.

In addition, modeling can be an integrating force for the environmental research community, in that the imposition of modeling requirements yields helpful insights in identifying needs and opportunities for new research. However, the use of models must be accompanied by continuing efforts to validate them.

Only with research continuing over many years, and for projects that extend over a substantial period of time and that are focused on fundamental issues, will the Nation be able to develop the credible and necessary expertise to better rationalize environmental management policies. Environmental science needs a critical mass of talent and resources to effectively approach the challenge of understanding complex environmental and health phenomena.

MONITORING AND ANALYSIS

One of the recommendations made by the panelists is of primary concern to you. It concerns data monitoring, collection, and analysis.

Monitoring yields essential current and time series information on the status of environmental systems, information used both for environmental management and for regulatory compliance. The panelists believed that the lack of coordinated scientific procedures accounts for such problems as nonstandardization of monitoring practices and failure to monitor for parameters of greatest importance or relevance.

In spite of significant efforts expended on the collection of environmental data by a variety of unrelated and uncoordinated State and Federal agencies, no adequate system exists for the integrated collection, storage, maintenance, and quality control of such data. It was recommended that CEQ foster an evaluation by an appropriate organization of existing physical, chemical, and biological monitoring programs (and extant data associated with them) to identify and stimulate research and development on improving the quality and cost effectiveness of monitoring programs. Particular emphasis should be placed on determining requirements for biological and environmental monitoring, on identifying pollutants such as toxic chemicals for sampling, and on determining information and statistical requirements for environmental models.

In this regard, the Council has addressed the idea of an Interagency Initiative on Environmental Monitoring and Data. There are several compelling reasons to revisit the environmental monitoring issue from a comprehensive, multiagency perspective. You are all concerned with the collection and sharing of data and the need for better ways to accomplish your given tasks. Recent studies point to the continued need for improvement in the monitoring of environmental trends, and in the more effective dissemination of information on environmental quality to all concerned organizations and individuals.

In addition, there is clear Congressional interest within the last 2 years pointing to the need for resolution of monitoring problems, and proposing a national environmental monitoring commission to do what the agencies themselves could be doing. The increasing budgetary austerity that most agencies will face argues for the use of common methods, cooperation in monitoring common parameters, standardization of methods, and the pooling of data.

CEQ AS CATALYST

Because of its location within the Executive Office of the President and the Council's responsibilities relative to environmental information, CEQ can effectively serve as the catalyst to encourage multiagency cooperation in this area. What we propose is the following:

> To establish a core group within the Council on Environmental Quality and an oversight committee composed of representatives from Federal agencies to undertake such tasks as:
>
> 1. Update and publish a report on Environmental Trends in the Nation.
> 2. Identify an aggregate set of key environmental indicators capable of assessing the environmental health of the nation.
> 3. For each indicator proposed, recommend an approach for collecting and aggregating data, under which measurements can be obtained regularly and cost effectively.

You in this room today well realize that comprehensive environmental management approaches depend upon the availability of reliable theories, data, and expert opinion. Advances in environmental sensors, information processing, transfer of scientific and technical knowledge, and use of environmental data bases can increase our ability to effectively manage our environment.

SOME BASIC QUESTIONS

Basic scientific research, and monitoring and assessment activities, provide useful but voluminous amounts of information that must be evaluated to assure its reliability in identifying, resolving, or mitigating environmental problems. However, in identifying long-term research and development needs, it is important to first distinguish between research and monitoring; that is, between studies that attempt to improve our understanding of how environmental systems work, and studies that provide data on the status of those systems. Our basic understanding must guide the choice of what parameters to monitor, and questions of research priorities and quality control must be answered.

In order to improve methods of data analysis and interpretation, a number of additional questions must be answered. For example, how are the large environmental data sets currently maintained by the Federal regulatory and management agencies being used? Are they used in state-of-the-art models and analyses that are clearly related to human health and environmental quality and which reflect our knowledge of how systems work? Are they ever used to improve our basic understanding of how systems work? How many people outside the agencies use the data? What are the problems and impediments in using and interpreting the data? Has basic knowledge about the working of the systems being sampled been used to increase the efficiency of sampling and the utility of the data in detecting trends?

Through your efforts in the development of environmental information resources, you can help evaluate the cost effectiveness of previously implemented programs, while identifying where additional efforts are needed, thereby determining where funds need to be allocated. You are able to assist in the promotion of new programs by substantiating the effectiveness of other similar programs and to justify budget requests for these programs.

Proper management of our wilderness system supplies researchers with living laboratories to provide vital base line data. Wilderness thus is offering our Nation more than recreation opportunities alone. Wilderness is a vital part of the national interest in environmental quality. I want to commend you for your interest and good work. Please accept my sincere good wishes for the future.

AUTHOR

A. Alan Hill
Chairman
Council on Environmental Quality
Washington, DC 20006

INTRODUCTION TO WILDERNESS RESEARCH NEEDS PANEL DISCUSSION

William A. Worf

To this point in the conference we've reviewed wilderness research findings and perspectives after more than 20 years of living with the 1964 Wilderness Act—a kind of "state-of-the-art" review. It is extremely important that we stop occasionally and take stock of where we are and how we got here. But the greatest value of such an assessment is to establish a base from which to plan and launch future programs. This morning we have a distinguished panel representing wilderness users and administrators. The panel's charge is to tell the conference from their perspective what issues/problems/opportunities are confronting wilderness managers which the scientific community can help to resolve.

There are several precepts that managers and researchers alike must keep clearly in view as we struggle to maintain an enduring wilderness resource for this and future generations. Before introducing the first speaker, I'll briefly review five of these.

LEGISLATIVE BASIS NECESSARY

First: Everything we do in both management and research must be firmly based on the Wilderness Act and its legislative history. Speakers in this conference have repeatedly reminded us that the term "wilderness" has different meanings to different people. Harold Eidsvik told us that other nations have difficulty understanding the concept. That is not surprising because the concept is uniquely American—it flows from our pioneer heritage.

While a number of our philosophers and naturalists have written extensively about wilderness, the concept embodied in the U.S. National Wilderness Preservation System doesn't come from any one of them. The concept isn't Henry David Thoreau's, Aldo Leopold's, John Muir's, Art Carhart's, or Bob Marshall's. It contains elements from the philosophies of all of these men—and those of other people. It is a composite of ideas and compromises forged in the heat of Congressional debate for 8 years.

There are very few of us that would not like to change some aspect or provision of the Act to make it conform more closely with our personal idea of what wilderness should be. However, if managers and researchers allow these personal biases to guide management decisions or influence research designs, our wilderness system will soon be only a "grand experiment" that failed. Each manager's personal bias would take every wilderness in a different direction. Each of us has an obligation to future generations to make the whole idea work as designed in the Act.

WILDERNESS IS FOREVER

Second: Wilderness is forever.

Rod Nash told us yesterday we should not justify the establishment and maintenance of wilderness simply for the future. I agree. It is important for us here and now. Nevertheless, we are charged by the Wilderness Act to maintain an enduring resource of wilderness for this and future generations. Our greatgrandchilderen—or theirs—may have no interest in wilderness as defined in the Act, but we must provide them with the option.

We need to be constantly aware that even seemingly small impacts of shortsighted management rationalizations and precedents could have cumulative effects that will destroy the system gradually over the years. Conversely, courageous decisions like the one recently made by Forest Service Chief Max Peterson will gradually strengthen the system. Max refused to allow EPA to take the "easy way" and use helicopters on wilderness lakes to complete the Western Water Survey. There is no question about the importance of that study to determine the effects of acid rain, but Max said it could be done without resorting to helicopter use. He said if EPA people didn't have the ability or commitment to get the job done the wilderness way Forest Service people did. Forest Service people will collect the samples using foot or horse travel methods. Hundreds of similar potential impacts confront the wilderness system each year.

ONLY ONE PIECE

Third: Wilderness is only one piece of the conservation picture.

Those of us who love the wilderness may sometimes get so engrossed in the battles of designation and management we forget that its very existence depends on how well we manage those lands outside of wilderness. To maintain areas where primitive recreation and outstanding opportunities for solitude will always be available we must provide adequate opportunities for those who want to enjoy the outdoors from the seat of a trail cycle, snowmobile, or automobile. To keep some areas where forests will live, die, and regenerate themselves in a truly natural way we must provide elsewhere for the sustained yield of timber, forage for livestock, or managed habitats for wildlife and fish.

Wilderness can furnish knowledge that will help mankind feed, clothe, and shelter itself. We as wilderness supporters must see that this knowledge is put to use, and we must take positive steps to ensure that lands managed for the production of other resources are managed to produce a sustainable flow of those resources.

ONLY ONE VALUE

Fourth: Recreation is only one of the values of wilderness.

When I first became involved in the management of the Bridger Wilderness some 24 years ago I viewed it as a recreation area—a somewhat esoteric one to be sure—but a recreation area nonetheless. Subsequent study and work has impressed on me the fact that while the majority of those using wildernesses directly are recreating, recreation is not the most important long-term value of wilderness. Preoccupation with recreation has led to the suggestion by some people that equipment, structures, installations, or activities that are generally prohibited will have little or no adverse impact on wilderness if current recreation users don't object or if the activity can be hidden from them. They would say a set of camouflaged instruments, a power saw outside the heavy recreation season, or the landing of a helicopter in winter are really OK. Hiding such activities or things will reduce the impact on current recreationists. It will not, however, prevent the cumulative erosion of the wilderness character of the land.

Just as wildernesses are not recreation areas, neither are they elk ranges, research areas, or scenic areas. The wilderness resource must take priority in resolving all conflict to the extent not prohibited by the Act's special provisions. This determination by managers that the wilderness resource is dominant has led to concern by some scientists, as expressed in this conference by Jerry Franklin and others. They say that research activities are being discriminated against. Some scientists have pointed to the scientific purpose listed in the Wilderness Act and asked permission to conduct research that involves the use of aircraft, structures, instrument installations, or some form of vegetative manipulation. They have often been unhappy when their requests are denied. The Act makes it clear that the gathering of information about resources is authorized but it must be "carried on in a manner compatible with the preservation of the wilderness environment" [Sec. 4.(d)(2)].

MUST BE GUARDIANS

Fifth: Wilderness managers must be GUARDIANS not GARDENERS.

This was an admonishment often given to administrators by Howard Zahniser, Executive Director of the Wilderness Society, during the long Congressional debate over the Wilderness Act. Man has a driving urge to improve or fix things. Over the past 21 years I've listened to many urgent and sincere pleas from managers who want to use their management skills to "improve" vegetative diversity, esthetics, or wildlife habitat in wilderness. Others want to give Mother Nature a helping hand to fix something that our predecessors may have fouled up.

The vast majority of these proposals for manipulation by man would only further confuse and obscure the natural processes. They would damage the wilderness resource, not fix it.

If we are guided by these precepts we will maintain an enduring resource of wilderness.

AUTHOR

William A. Worf
Environmental Consultant
Forest Service, USDA (retired)
Stevensville, MT 59870

WILDLIFE RESEARCH NEEDS IN WILDERNESS AREAS

Lynn A. Greenwalt

Having been involved with the management of designated wildernesses since the very first ones were established, I have always harbored a concern which is related directly to the question at hand.

That concern, stated simply, has to do with how wilderness should be managed so as to serve the purpose and intent of the Wilderness Act. Should wilderness be managed, in the literal sense of that term, in order to maintain the kinds of wildlife and habitat relatively typical of those areas in their pristine state, or should it be left alone to evolve in accordance with the influence of natural processes as they are presently constituted?

DISTORTION POSSIBLE

Obviously, very large wildernesses are more nearly subject to the functioning of natural processes that are not dissimilar in their impact to what would have occurred in times before European man began to exert his considerable influence. However, even these larger areas are affected by human inclination to control wildfires and to introduce pervasive and possibly significant pollutants into the air (acid rain), and they also are influenced by cattle grazing, timber harvest, and various kinds and degrees of recreational use. Smaller areas are even more profoundly affected, of course, to the extent that the effects of fire, grazing by wild animals (bison), and other processes that made them dynamic are at least interrupted or may be foreclosed altogether. The result may be a distortion of the ecosystem—at least in terms of what we might expect, based upon what these areas were known to be like in former times—even to the point where they may be perfectly "natural" but hardly representative of wilderness in an historic sense.

The question is perhaps more one of philosophy than an identification of research needs, but it occurs to me that it might be fruitful to contemplate research to determine what it is people expect from their newly created wilderness heritage (including what they prefer to pass along to their successors). An obvious consequence of knowing this, of course, will be a need for research to determine how to make this happen, including an identification of the ways these lands should be managed (including manipulation) in order to realize the expectations of those for whom wilderness areas have been set aside.

A question derived from all this—or which should be addressed apart from the somewhat more cosmic concern outlined above—has to do with how fish and wildlife species have fared in established wildernesses. It might be unusually revealing to compare data from wildernesses to information obtained from the same or similar areas prior to wilderness designation. This should be done with selected nongame as well as game species, though game species are likely to be the ones the welfare and status of which are foremost in the minds of many wilderness users.

A PROVOCATIVE QUESTION

Finally, and provocatively, there is the kind of question which arises from the fact that the responsibilities for the management of resources in wildernesses are more often than not split between the State wildlife agency and the Federal land-management organization. This is a dichotomy of long standing, carefully crafted to recognize the fact that States have the right to manage the wildlife (including fish) and the Federal land managers have the responsibility to manage the habitat.

With wilderness designation there is a change in the way the land manager must approach his responsibility, based upon the idea of limiting human intrusion, controlling the nature of activities permitted, and a requirement that the lands so designated be managed in keeping with the tenets of the Wilderness Act. This may or may not pose a problem in that State agencies through which the wildlife are managed do not have the same restraints (if they are indeed restraints).

There may be a need to identify whether any major problems have arisen in wildernesses as between the goals of the State wildlife agencies and the goals of the land management organizations involved. There have, to be sure, been some at least brief conflicts concerning such matters as the use of aircraft to stock fish in remote areas in units of the National Wilderness Preservation System.

ARE CHANGES NEEDED?

It may be useful to determine whether there are many such problems, and if so, if they are widespread and of moment enough to pose problems now or in the future. Are they subject to resolution through presently available processes, or are regulatory (or statutory) changes needed?

These may be problems of small concern now, but it would be well to give them continuing and proper attention, since it would be tragic to have serious conflicts arise, perhaps to erode unnecessarily the aspirations and purpose envisioned for the Nation's system of wildernesses.

AUTHOR

Lynn A. Greenwalt
Vice President for Resources Conservation
National Wildlife Federation
Washington, DC 20036

QUESTIONS FOR FURTHER WILDERNESS RESEARCH

Robert E. Howard

The Sierra Club is a 350,000-member organization whose purposes are to explore, enjoy, and protect the wild places of the world. Since 1892, the Sierra Club has worked to preserve parks and wilderness. It is a "grassroots" organization of concerned, active citizens. Many of them are wilderness users as well as wilderness protectors.

From the Sierra Club's viewpoint, the following are particularly important issues and questions for further wilderness research:

1. Emphasis on protection of wild ecosystem information. This includes information contained in the gene pool, in unperturbed natural processes, and in wilderness characteristics. One of the most pressing areas is study of the quality, characteristics, and conditions of air, water, and soil in wilderness as a baseline for the effects of air, water, and toxic substances pollution.
2. Study the morbidity of wilderness flora and fauna due to pollution, as opposed to their mortality. The concept of wellness or healthiness of each component of the ecosystem suggests that research should concern factors causing morbidity, not just mortality. Especially focus on factors causing chronic, long-term morbidity, and the subtle interactions of such morbidity in ecosystem cycles and processes.
3. Determine exactly what occurs across wilderness boundaries as interfaces. What are the transboundary relationships and impacts of nonwilderness activities (sights, sounds, smells, pollution, movement of biota) on wilderness, and vice versa? Determine what potential management tools exist to address transboundary impacts.
4. Increase the study of desert and fragile mountain wilderness ecosystems. This is particularly important with the forthcoming Bureau of Land Management wilderness designations. There are related needs regarding international de facto wilderness areas.
5. Develop a means to assess the relative needs and values of managing the wilderness resource itself versus managing human users and usage of wilderness. There are various perceived needs and values in the management of fire, wildlife, biotic succession, pests, soil erosion, and water resources. Similarly, there are perceived needs and values in the management of recreational, research, grazing, mining, and other direct users of wilderness, and in indirect usage of wilderness for water resources, as an airshed, as a potential neutralizer of toxic substances in groundwater, etc.
6. Research methods of more effectively informing, affecting attitudes, and modifying behavior of users. Applied social psychological research directed toward identifying those methods amenable to development as management tools is needed. Although the first applications would presumably be to direct wilderness users, the same or similar methods would probably be useful with the general public.
7. Determine a priori what "immediate benefits" to wilderness would result from exception to the restrictions on motorized access in wilderness. The Wilderness Act requires immediate benefits to wilderness as the criterion for granting exceptions to the restrictions on motorized access in wilderness. Managers should have a clear notion of what benefits might result from a proposed exception. They should also have a clear set of guidelines to determine whether the benefits reasonably and probably would result. An example of the problem is the use of helicopters for acid rain research in wilderness.
8. Determine what mineral, oil, and gas leases are outstanding in wilderness. A database of current and accurate information would be useful to many. Related subquestions include: Under what conditions were leases issued? How many leases were grandfathered? How many were erroneously issued? How many are still valid? What is the cumulative impact of these leases?

AUTHOR

Robert E. Howard
Vice President
Sierra Club
San Francisco, CA 94104

PITFALLS IN WILDERNESS MANAGEMENT—LET'S AVOID THEM!

Clifton R. Merritt

Wilderness management and research have indeed come a long way in the two decades since the Wilderness Act was passed. Four days of this exceptional National Wilderness Research Conference have made this fact clear.

This alone vindicates those hardy pioneers back in the 1950's who said, "We need a national wilderness system under law." For, until the enactment of the Wilderness Bill in 1964, wilderness, like beauty, was in the eyes of the beholder. Even longtime wilderness buffs had widely differing views as to what wilderness was and how it should be managed.

But enactment of the 1964 landmark legislation changed that situation. The Act defined wilderness legally and spelled out how it was to be managed. Henceforth, wilderness was what the law said it was, and it was to be managed as the law provided. There was less room for uncertainty and subjectivity.

The law strengthened and gave direction to management and allowed research to move ahead. Both have prospered.

PITFALLS IN PROSPERITY

But in their prosperity there are pitfalls that both wilderness managers and researchers must avoid if wilderness is to survive.

They must recognize and accept the fact that wilderness areas are **not** primarily recreation areas. Recreation is not the only use of wilderness. The 1964 Wilderness Act specifically states that, "Except as otherwise provided in this Act, wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use."

Since the law does not mention priorities, each of these public purposes or uses is equal in importance under the law. They must be given equal consideration by management.

More than a few public land managers have been giving primary attention to the recreational aspect of wilderness. It is easy to do this. The recreational use is more visible, political. This is the anthropocentric approach. If it prevails, it will ultimately destroy wilderness.

The anthropocentric approach deals to a large extent with managing wilderness for man's use. It concerns itself with such matters as how the visitor **feels** about wilderness and its management. Thus, it can lend itself easily to too much subjectivity. Take, for example, the matter of whether a bridge should be built across a stream in the wilderness. Perhaps crossing the stream without a bridge presents some risk. But wilderness users to date have gotten by without it. And isn't all wilderness use at some risk? Where do you draw the line before you have so many bridges, hardened trails, and semideveloped campsites that the area may be a convenient recreation area but no longer wilderness? Let's face it. While wilderness management and research have come a long way since passage of the parent Wilderness Act, they still have a longer way to go in educating and continuing to educate the user public about wilderness. Conservation organizations have a major responsibility here, too.

Far too many users view wilderness as just recreation areas. And they have a wide range of thoughts as to how the areas should be managed. For them, consideration of the other public purposes of wilderness is in its infancy—or hasn't been born yet. Left on their own, many of them would tear up and trash up the wilderness—or love it to death. They need to be told much more about these other purposes of wilderness. They need to learn more about the biocentric approach to wilderness management, which focuses more on the biological and other physical resources of the wilderness.

Obviously, managers and researchers must employ a proper mix of both anthropocentric and biocentric approaches.

NATURE MUST PREVAIL

The bottom line in wilderness management is preserving the wilderness character. Man can always create a recreation area. But once destroyed, the primeval scene can never be restored. Wilderness management is largely managing the people who use the wilderness, so as to preserve its wilderness character. In wilderness, the forces of nature must prevail.

Another major consideration that I feel has not been adequately addressed at this conference is that wilderness is not an island unto itself. It does not exist in a vacuum. Moreover, it cannot continue to exist if the people responsible for managing and researching it do not look beyond its borders. We must avoid this pitfall.

Jim Posewitz, environmental director for the Montana Department of Fish, Wildlife and Parks, in an address last winter before the annual conference of the Montana Wilderness Association, said it best. He spoke of limits of acceptable change, as applied to the 1.5 million-acre Bob Marshall Wilderness complex in western Montana.

Said Posewitz, in part:

> Overuse of quality recreation opportunities or quality recreation areas is without a doubt a serious problem. We must be careful, however, not to focus solely on the wilderness as a solution. At issue here is not dividing the remnants of wilderness among the myriad of competing users or individuals seeking that wildness. Overuse of the wilderness will not be solved by restricting its users. It must be achieved by halting the taming of all nonwilderness remnants, by reclaiming substantial blocks of our increasingly battered forests, and by initiating a user education process.
>
> Wilderness is freedom. You can't ration, computerize, or regulate freedom. It's a contradiction in concept. We must all resist the debate over how we will limit ourselves and our use of the Bob Marshall Wilderness complex. The problem is really that, for some types of recreation, the Bob Marshall is all that's left. The solution to use problems in the Bob Marshall may lie in addressing what is happening to the rest of the public lands.
>
> If pressure must be relieved, then let us reclaim the Little Belt Mountains to the extent that we can once again have an early (and long) elk season. The same for the Bitterroots, the Big Belts, and other pieces of overcompromised wild country.
>
> The future of hunting, the future of fishing—the future of wildland recreation—does not lie in rationing the classified wilderness. The future of all these activities lies in the careful husbandry of all public lands and doing what is necessary for the reclamation of those lands that have been compromised excessively for the production of commodities alone.

To manage a wilderness area best for all its public purposes, then, we must understand how it is being affected by management of the nonwilderness public lands that surround it, and what we must do to eliminate or minimize the outside adverse impacts to the wilderness resource itself.

INVOLVEMENT NEEDED

Finally, managers and researchers can manage and research wilderness until the end of time, but if they don't involve in their work the people who use the wilderness, they will have but little to show for their efforts. For this reason, I would like to have seen many more leaders of environmental groups attend this conference. Many of their people use wilderness. By acquainting the leaders with wilderness management problems and research implications, and by obtaining their enthusiastic involvement in solving these problems, you will have advanced a hundredfold the noble work in which you are engaged.

AUTHOR

Clifton R. Merritt
Executive Director
American Wilderness Alliance
Englewood, CO 80112

INSTITUTIONAL RESEARCH FOR A DEMOCRATIC WILDERNESS POLICY

Bernard Shanks

We are things forgotten when the ice withdrew,
and meant to perish really,
but the ice forgot, and somehow from the ice-streams
we survived
—a tough ill-mannered beast, out thinking all the rest.
There's just one thing: whatever made us never taught
how to out think ourselves.
From "Why Does the Cold So Haunt Us?"
—Loren Eiseley (Eiseley 1977)

The most troublesome issues and problems confronting wilderness lands are also the most difficult for traditional researchers. It is easier, for several reasons, to cast the net of science over manageable fry like the user, entrepreneur, wildlife, or other resource or experience. Nevertheless, it is appropriate to consider the fundamental problems which threaten wilderness—political processes, and managers, public land, and educational institutions. The questions in this arena are many and essential:

- How in our democratic society does wilderness conservation compete with private economic activities?
- How does society craft the institutional structure for public land management which adequately serves the public and future generations?
- How are land managers trained to serve the public interests rather than the private commercial sector?
- What is the role of our universities in wilderness education and research?

The problems of wilderness management and protection are ingrained in the very fabric and structure of public land management institutions. Until we address the structural problems with research meaningful in a political-policy environment we will fail to have a truly democratic system of land management. These problems go beyond the usual philosophical conflicts of protection vs. development. They concern whether we will have a public trust system of land management or a system by management elites for economic elites.

When public land products are viewed in an economic framework we find the land management agencies are subsidizing virtually every commercial activity on the public domain. In the political arena we find a rise not in a public trust but a rationalization of private greed—first in the guise of the "Sagebrush Rebellion," more recently in the form of "privatization" theory. The institutions which once implemented a major revolution in American society, conservation, now are unwilling or unable to refute fashionable political or economic trends.

DRAMATIC CONTRASTS

Today's specialization of public land managers, educators, and researchers has taken the subject of public land policy far afield from its historic principles. Yet the writings of Teddy Roosevelt and the pioneers of our profession rested on a solid ethical foundation. When have we seen or heard the ethics of public land management discussed by our leaders today?

Roosevelt, in dedicating a new entrance to Yellowstone, could say, "I cannot too often repeat that the essential feature in the present management of the Yellowstone Park, as in all similar places, is its essential democracy—it is the preservation of the scenery, of the forest, of the wilderness life and the wilderness game for the people as a whole, instead of leaving the enjoyment thereof to be confined to the very rich who can control private reserves" (Roosevelt 1926).

The contrast with today's management of public lands is dramatic. Frequently we see a handful of individuals, sometimes one person, directing public land management and wilderness policy. Today, the Federal land agencies devote most of their energy—staff time, resources, and money—the very things we measure in public policy analysis—to the subsidization of private economic activities on public lands.

The program failures of the agencies have been more specific than a drift into a welfare role. Despite a clear policy mandate the land management agencies have largely failed to prevent continued erosion and degradation in the quality of public lands. The agencies have failed to provide efficient management based on the least costs and maximum public benefits. We have a failure to develop meaningful partnerships with States and local government, or to prevent wasteful interagency conflicts. Even a seemingly simple program like the consolidation of public lands becomes hopelessly bogged down. Finally, the agencies have failed to respond to national publics and changing environmental values.

Wilderness as a public policy has been and still is opposed by the very institutions that are charged with the management of wildland. The result is a shortage in the supply of wilderness. The agencies provide indifferent, if not hostile, wilderness management. Overall there is a lack of resources, including research, directed toward one of the most democratic forms of land conservation.

Pinchot wrote in his autobiography, "Everyone knew that neither money or political influence could dictate to the Forest Service . . ." (Pinchot 1947). Today, the activities of the Forest Service are largely concerned with money—economic activities on the National Forests—and no one could deny the special interest political influence over the management of public forest lands. The land ethic of early conservationists like Roosevelt and early foresters like Aldo Leopold does not fit the fashion of today's political climate.

PROBLEM CORE

How did our agencies fail the public trust? What has been the role of the "professional" in land management? A recent **Journal of Forestry** article gives some indication of the role of chauvinism and management elites in public land management: "Many foresters see this second campaign (against preservation) as the defense of the profession's very underpinnings." The article goes on to lament the "rising tide of preservation" and calls politics the greatest obstacle of all to professional forestry (Heinrichs 1985). To me this paternalistic, elitist attitude of foresters and range managers has been the core of wilderness conservation problems. It advocates a technocratic approach to a public trust subject. The phenomenon seems an appropriate subject of wilderness research.

- What has been the cause of the land management bias against wilderness?
- Why has the public trust in public lands been largely lost in today's policy discussions?
- Are today's professionals lacking in the foundation of history, philosophy, and ethics which the early leaders held at the core of their work?
- How does a profession, a group of land managers, working on public lands, set itself above the democratic process and develop hostility toward the political process?
- Why have the land management professions, at one time at the forefront of a great political and social movement, now become the last to accept changing values and attitudes toward land, endangered species, preservation, and wilderness?
- What role have our universities played in this process?

We need research on these tough, but fundamental, questions rather than the easy ones regarding the social-economic characteristics of wilderness users.

More importantly, we need research on how we can train and prepare public land managers with a professional orientation toward what Roosevelt termed the "public as whole."

Finally, what institutional structure do we need for the long-term management and protection of wilderness? It seems increasingly obvious that the multiple-use agencies have failed to respond to the national public needs in the area of wilderness conservation.

- Do we need a new agency to protect and manage wilderness?
- How would we develop the framework for such an organization and how should it be staffed and supported?
- If that approach is not feasible how do you change relic managers and aging institutions?
- How are social changes and democratic processes incorporated into public agencies?
- How does the public gain control of public trust lands and for the next several generations assure that the management will not be dominated by special economic interests?

REFORM REQUIRED

Undoubtedly, educational reform is required for national resource programs. The narrow, highly specialized vocational training must give way to broader education. Emphasis should be on communication, ecology, and the ethics and philosoply of quality land management. Most important, public land managers should have a clear understanding of the democratic process, with its flaws, that is the political process.

Research emphasis should be broad and holistic. Policy research, which measures results and efficiency, should not be buried in dusty archives. Instead, the results must be directed toward the key leverage points in the policy process and launched into the public arena for debate and discussion.

Undoubtedly, these questions are not likely to be researched by the agencies themselves nor the landgrant universities that conduct most wilderness research. It is easier and more politically comfortable to research the smaller, more manageable questions. Such questions will have to be addressed, most likely, by the private nonprofit conservation community or the new Wilderness Research Foundation.

REFERENCES

Eiseley, Loren. Another kind of autumn. New York: Charles Scribner's Sons; 1977. 78 p.

Heinrichs, Jay. Pinchot's heirs. Journal of Forestry. 83(5): 277-279; 1985.

Pinchot, Gifford. Breaking new ground. New York: Harcourt, Brace and Company; 1947. 515 p.

Roosevelt, Theodore. Dedication speech for Yellowstone National Park, April 24, 1903, Gardner, Montana. In: The works of Theodore Roosevelt; national edition. New York: Charles Scribner's Sons; 1926.

AUTHOR

Bernard Shanks
Chief of Planning
Arizona State Parks
Phoenix, AZ 85007

WILDERNESS ISSUES AND PROBLEMS THE SCIENTIFIC COMMUNITY CAN HELP RESOLVE

Steven Child

The Aspen Wilderness Workshop is conducting a baseline monitoring project in the Maroon Bells/Snowmass Wilderness located in west-central Colorado. The project is being done in cooperation with the Aspen District of the Forest Service, U.S. Department of Agriculture.

The Maroon Bells/Snowmass Wilderness is probably the second most heavily used wilderness in Colorado, after the Indian Peaks Wilderness, which is located near the Front Range urban area. Parts of the Maroon Bells/Snowmass Wilderness are very overused, and the Forest Service is searching for a method of trying to reverse the trend.

This baseline research project is designed to measure several parameters that can be checked annually or semiannually. The information collected will be used to determine if the condition of the wilderness is improving or deteriorating, and will help the Forest Service determine what management steps need to be taken in an individual section of the wilderness.

The four areas being studied include: campsite condition, trail condition, vulnerability of lakes to acid precipitation, and user response to the social condition (how many people are using the wilderness and do the users perceive it as being too crowded or overused).

MAROON BELLS/SNOWMASS PROBLEMS

Problems presently occurring in the Maroon Bells/Snowmass Wilderness include:

1. Too many people in popular areas around lakes and hot springs has led to degradation of campsites through soil compaction, loss of vegetation, lack of firewood, and sanitation problems including *Giardia* contamination in the water.

2. Loss of wilderness-type experiences and lack of solitude.

3. Pressure on wildlife species (you see essentially no big game species in the overcrowded areas).

4. Conflicts between livestock grazers and hikers due mostly to overgrazing along creek bottoms where the hiking trails also tend to be. The Forest Service has responded in some instances by closing areas to grazing, and in others by shifting to better grazing management techniques.

5. Severe erosion on trails leading to popular climbing routes. These trails often go straight up very steep hillsides.

6. Threat of a deterioration of air quality due mainly to development upwind of nearby oil shale facilities. Other wildernesses in the State are being impacted by coal-fired power plants.

7. Conflicts caused by outfitter use, including permanent camps in some areas, and trail erosion from too many horses.

8. Potential problems due to the introduction of llamas to the Colorado high country. What are the long-range implications of introducing a South American animal into our Country?

OTHER WILDERNESS PROBLEMS

Problems occurring in other Colorado wildernesses include:

1. Pine beetle infestations. This problem tends to be self-limiting in high-elevation areas where most present wildernesses are located. What efforts, if any, should be made to control it?

2. Water diversion projects, especially in the Holy Cross Wilderness and the proposed Williams Fork Wilderness. The answer to this problem may lie in the development of water-saving measures and technology in the Front Range urban areas that are proposing to divert the water.

3. Damage caused by mountain bikes on trails in nonwilderness lands.

4. Mining.

MAJOR ISSUES

1. Should the Maroon Bells continue to be a sacrifice area to help keep too many people from going to less-used areas, or should efforts be made to direct people to less-used wildernesses or nonwilderness areas to spread the impact out?

2. What heroic measures should be taken to try to minimize the impact of man in wilderness, such as hardening the trails with gravel, or building safe bridges?

3. At what point should wilderness managers begin limiting the numbers of people going into an area to protect the resource? Random questionnaires handed out in the Maroon Bells/Snowmass Wilderness indicate that most people do not feel it is too crowded, even when numbers of trail encounters and campsites occupied indicate that capacities are already exceeded.

4. Should a permit system be started? What parameters should wilderness managers be using in determining when an area becomes too crowded? There is a need for baseline data and methods of developing easily quantifiable measurements which would be useful to wilderness managers.

SOLUTIONS AND OPPORTUNITIES

1. The solutions to some of the problems lie in areas outside the regular realm of wilderness management. For example, the development of water-saving technology could lessen or eliminate the need for a major water diversion project in the Holy Cross Wilderness in Colorado. Air pollution control regulations and technology applied outside wilderness (like in the oil shale area or copper smelting areas) would help lessen air pollution inside wilderness. Development of new camping gear such as camping stoves can help preserve campsites and trails.

2. Can space-age technology help in managing wilderness? An example of this would be to determine the extent of the impact of man through the use of satellite photographs.

3. There is a need for baseline studies to be done now in many wilderness areas to determine the extent and type of wilderness use, the condition of trails and campsites, the condition of wildlife populations, and air and water quality, especially to determine the extent of acid precipitation damage.

4. There is a need to find more accurate ways to quantify damage to vegetation by acid rain. We shouldn't study just lakes, but should study the forests before they start dying.

5. We need to develop better techniques for polling wilderness users, and educating them.

6. We need to determine the long-term effects on the backcountry of mountain bike and llama use.

7. We need to develop a Wilderness User's Pill to lessen the urge of people to go to the wilderness, and to make them more aware of and sensitive to their surroundings when they do.

AUTHOR

Steven Child
Co-chairman
Aspen Wilderness Workshop
Snowmass, CO 81654

NEW CHALLENGES FOR WILDERNESS RESEARCH

David E. Porter

Most of you have heard the phrase "the new kid on the block" used when referring to the Bureau of Land Management and our managing of wilderness areas on the public lands. This phrase is certainly appropriate when applied to our new wilderness responsibilities. But it is just as appropriate when considering our wilderness management research needs. As it is with the kid in a new neighborhood, BLM is also going to confront its fair share of new challenges when managing wilderness, and will have to rely on its well-established "neighbors" to help adjust and meet these challenges for achieving the basic goals of wilderness management.

Compared to the responsibilities of the other three Federal agencies managing wilderness, BLM's 369,000 acres of wilderness in 23 separate units, ranging in size from a 5-acre island on the Oregon Coast to the 110,000-acre Paria Canyon/Vermilion Cliffs Wilderness in Arizona, hardly seems worth discussion. This will not always be the case. Out of the 25 million acres now under study by the BLM, the potential exists that 8 to 10 million of those acres will eventually be designated wilderness. This still seems small when compared to a wilderness system today of 88 million acres. But the BLM wilderness system does already, and will to a greater degree in the future, contain a tremendous diversity of ecosystems, resource values, and management challenges. Let me mention some topics on which we need research.

Arid-type Ecosystems.—Many of BLM's wildernesses will be located in arid and semiarid regions of the Country. These fragile ecosystems recover slowly from impacts and will require specialized management. Also, BLM wildernesses will be relatively small in size and will contain only fragments of larger ecosystems, creating tremendous outside pressures and potential impacts. We also look to research to help in finding the best ways of reclaiming disturbed desert ecosystems.

Concentrated Public Use.—This can be a big problem, especially in the canyon country. BLM has a lot of canyons under study, and some have already been designated as wilderness—Aravaipa and the Paria in Arizona, and Bear Trap Canyon in Montana. These steep, narrow canyons tend to concentrate and funnel visitors, placing most of the pressures on small portions of the resource. Also, the arid nature of BLM lands tends to concentrate use where water is available. Many of these water sources can sustain little impact. Wildlife is dependent on the same sources; and, in many instances, archaeological sites are also located here.

Ill-defined Boundaries.—We know where they are, but the public may not, because they are not always tied to distinct landforms. This can lead to trespass by offroad vehicles and miners. Are there better ways to handle this problem, short of going all out with signs and fences? We look to research for help.

Recreation Use Is Not the Major Impact.—Emphasis on management, and ultimately the research emphasis, for many BLM wildernesses will not follow the same direction as found in today's wilderness system where managing recreation use is the primary focus. Our needs will be slightly different. Recreation use may not be the major force affecting the wilderness resource. Many BLM wildernesses will be remote, isolated, away from population centers, and will see few recreationists.

Fire Is a Major Management Concern.—For example, some wildernesses in Nevada, eastern Oregon, and southwestern Idaho will have a greater impact and management concern from fire. To make sound wilderness fire management decisions that follow the Bureau's policy of allowing fire to play a more natural role in wilderness, we need to know more about fire histories, the effect of various fire suppression methods on wilderness ecosystems, fire management techniques (such as prescribed burning), and the effects of fire on wildlife, the social/human conditions, and air quality.

Grazing Management.—Another major research need BLM will be confronted with is in managing the nonconforming uses allowed by the Wilderness Act, especially grazing. Many BLM areas now under study for wilderness contain grazing activities, and these activities will continue after the area becomes wilderness. Research can help us in determining compatible grazing levels, the amount of livestock forage to allocate in various types of ecosystems, and how these affect the wilderness resource and recreation use values of an area. Considerable research to date has been carried out on questions related to livestock grazing and the effects of grazing on various ecosystems. What we need is further information specific to BLM wildernesses and ecosystem types, and the overall effect of grazing on different wilderness characteristics.

Collection of Basic Resource and Visitor Use Data.—Most public land areas entering the wilderness system lack basic information necessary for managers to make intelligent decisions. Development of wilderness management plans for each wilderness is a top priority for BLM. Without a reliable data base, sound management decisions cannot be made nor can we be sure objectives laid out in management plans are being achieved. Research can also assist in establishing Limits of Acceptable Change (LAC) and in identifying the indicators and standards for setting these limits.

Applicability of Past Research.—Past research on wilderness user behavior, recreation use and impact, and visitor management will be partially useful to BLM because we will have similar problems on the public lands. But some of it may not apply in BLM wilderness because of the types of ecosystems and resource conditions, different impacts, or differences in visitor behavior. Researchers may need to reevaluate these findings and determine their applicability on BLM lands.

Unfamiliarity With the "Minimum Tool" Standard.—BLM field managers are unfamiliar with the "minimum tool" standard. Everybody thinks a pickup truck or helicopter is the minimum tool for their activity. We are already receiving numerous requests to continue paleontological studies, wildlife transplants, and archaeological research. And each requestor feels they should be allowed to conduct their activities as they were prior to wilderness designation. What can research do to help us manage these requests?

Communication and Education.—Because of the types of problems discussed previously, and the limited budget for BLM wilderness management, providing information and education to the public and our managers becomes extremely important. We need to know the most effective methods of communication—those which most effectively change visitor action. The research focus on the use of education as a wilderness visitor management technique to be carried out over the next 5 years at the Forest Service's Intermountain Research Station will be most useful to the BLM.

One last research need for BLM concerns coordination, cooperation, and technology transfer. We need to continue to improve in each of these areas. An agency as small as BLM, with extremely limited wilderness management dollars and the potential wilderness management responsibilities we will have, is going to continue to depend upon other agencies, universities, user groups, and the scientific community to develop the knowledge and suggested solutions necessary to help us properly manage wilderness on the public lands. This can only be achieved through good coordination and cooperation and by being aware of new technologies in the field.

To sum up, we want your help in focusing on the research needs of BLM wildernesses. Challenges await the wilderness manager as well as the researcher.

AUTHOR

David E. Porter
Division of Recreation, Cultural,
and Wilderness Resources
Bureau of Land Management
U.S. Department of the Interior
Washington, DC 20240

MANAGING THE WILDERNESS RESOURCE WITH KNOWLEDGE: IMPORTANT WILDERNESS MANAGEMENT ISSUES NEEDING RESEARCH

Ed Bloedel

When choosing research topics, both managers and researchers must take their direction from the Wilderness Act. Here are four important Wilderness Act directions, five major management issues with research needs, and two challenges to managers and researchers.

WILDERNESS ACT DIRECTIONS

1. Allow natural processes to operate freely. We must provide areas "...where the earth and its community of life are untrammeled by man ...." [2(c)]
2. Provide "... outstanding opportunities for solitude or a primitive and unconfined type of recreation." [2(c)]
3. Preserve the wilderness character of the areas. In every management action we take or everything we allow in wilderness it is our responsibility to preserve the wilderness character of the area. As the law states "... each agency ... shall be responsible for preserving the wilderness character of the areas ..." while administering the area for "... public purposes of recreational, scenic, scientific, educational, conservation, and historical use." [4(b)]
4. Manage for special exceptions provided for in the Act and subsequent acts "... as also to preserve its wilderness character." [4(b)]

WILDERNESS MANAGEMENT ISSUES

1. Effectively developing a true wilderness philosophy and ethic in managers, visitors, and researchers (this will go a long way toward solving most of the other issues listed here today). Research needs:

- Identify and develop effective educational techniques and identify target audiences.
- Develop methods to promote desirable human behavior in wilderness.
- Strengthen content of educational material.
- Develop methods to gather information about users and resources without permanent equipment or motorized use.

2. Protecting natural processes (keep "untrammeled") in the face of increasing human pressures and demands to alter the processes for special purposes (certain recreational activities, huntable game species, cloud seeding). Research needs:

- Understanding basic ecosystem processes and interactions.
- Describing plant succession.
- Describing animal species and natural population cycles.
- Describing the natural role of major ecosystem disturbances such as fire, storms, and insect and disease attacks.
- Describing ecosystems not well studied in the Southwest, Southeast, Northeast, and Alaska.
- Understanding the extent of human influence on natural processes including pollution originating outside wilderness.
- Describing the effects of management actions on ecosystems. This is particularly important as we need to develop more "sensitive management systems." For example, present insect control research has led to destructive insect control projects and methods. More work could be done to develop an insect control method that is more "sensitive" to maintaining wilderness character.
- Developing effective monitoring techniques.
- Developing more effective indirect methods of changing visitor behavior to prevent overuse. We need more "light-handed" visitor management techniques.

3. Maintaining "outstanding opportunities for solitude" in the face of increasing pressure for exceptions for special purposes (gathering information with motorized equipment, running horse or human endurance races, doing wilderness management jobs with motorized equipment). Research needs:

- Identify solitude tolerance limits.
- Identify when approved motorized use (Alaska Law) becomes too much.
- Develop methods to manage without motorized equipment.

4. Protecting wilderness from outside pollution sources and from presently "uncontrollable" uses such as low overflights. Research needs:

- Develop methods to control the "uncontrollable."
- Develop effective monitoring techniques that in themselves also preserve wilderness character.

5. Preserving wilderness character while managing special exceptions provided for in the wilderness and subsequent acts. This topic has not been adequately discussed in the wilderness research symposium. Research needs:

- Develop less impactive mineral/oil and gas exploration methods and techniques and improved restoration methods.
- Develop grazing systems that protect wilderness values.
- Develop effective educational techniques to teach ranchers and miners wilderness values.
- Develop effective educational techniques to teach wilderness visitors about the Wilderness Act's provisions for grazing and mining.

CHALLENGES

Here are two challenges I offer the research community. You need to develop with wilderness managers truly interdisciplinary wilderness research projects that start from the premise of protecting the wilderness resource first, then integrate all the other biological and social components of wilderness in a manner that preserves the wilderness resource. All research to date and presentations in this symposium have centered around individual components of the wilderness resource and have been accomplished by single disciplines. This single-discipline emphasis tends to place too much importance on managing one aspect of the wilderness resource that may conflict with another. An example might be recreation use versus a threatened or endangered species. Managers also must improve the involvement of the various disciplines necessary to do a better job of wilderness management.

Before I state my second challenge, I wish to lay to rest the myth that the Forest Service discourages research in wilderness. The Forest Service strongly supports research in wilderness that is done ". . . in a manner compatible with the preservation of the wilderness environment." [4(d)(2)] To protect the wilderness environment by keeping it "untrammeled" and providing "outstanding opportunities for solitude," we discourage the use of motorized equipment and the installation of instruments. For the same reasons and to keep wilderness from becoming overcrowded, we discourage research in wilderness that is not dependent on a wilderness environment.

My second challenge is: why is it so hard for the researcher (or the manager for that manner) to accept this "sensitivity" to the protection of the wilderness character while gathering data? Are we so hung up on "modern technology" that we cannot keep it out or hold it to the "minimum necessary" in wilderness?

AUTHOR

Ed Bloedel
Wilderness Management Specialist
Forest Service
U.S. Department of Agriculture
Washington, DC 20250

FISH AND WILDLIFE SERVICE WILDERNESS RESEARCH NEEDS

Marvin L. Plenert

Basically, the Fish and Wildlife Service has two distinctly different types of areas that have been designated as wilderness. They are (1) true wilderness or areas that fit everyone's description of what wilderness should be or is, for example, in Alaska and some larger areas in the lower 48 States, and (2) lands that simply have a wilderness designation and really don't fit the true wilderness concept. These areas are small (many less than 5,000 acres) and do not possess true wilderness qualities, as they have definitely been trammeled by man.

The problems of managing these wilderness areas, as well as the research needs, are quite different for each area, depending on where it is located. In the lower 48, the problems are mainly from outside influences, such as adjacent land uses, as many areas are reverted farmland that was once in private ownership, very flat, and only distinguished from adjacent land by a fence or a road.

From within many of our wilderness areas, one can see farmers working in their farm fields, towns, farm headquarters, highways and associated traffic, and powerlines, therefore detracting from what visitors gain from other wilderness experiences.

MANAGEMENT PROBLEMS

Because of the close proximity of adjacent privately owned lands, we have experienced problems with noxious weeds which of course are in violation of local weed district regulations, vehicle trespass, and a host of other problems. There is also a problem with water quality or runoff from adjacent land. Some of the problems with management and grazing of livestock have been inherited with wilderness designation, and require fences and watering facilities to maintain. Of course, they require vehicle access. Fire is also an important management tool, and of course there is the problem with smoke. We also have some areas with outstanding mineral rights, and the third party has the right of ingress and egress to gain access to mineral development.

Many of these problems can and have already been solved by our agency through management and education of the public. These problems do not, and will not, require research projects to solve.

Even though many of the areas are not true wilderness, the Fish and Wildlife Service is grateful for the added protection afforded to the land by the wilderness designation.

For our true wildernesses the problems and research needs take on a different twist. In Alaska, most of the State is wilderness, small "w," and therefore areas designated as wilderness tend not to be appreciated by many users or visitors. In some areas, too many visitors are competing for the resources that are available, and most are located in very fragile areas. The use of motorized equipment has been built into the establishing legislation of some areas, thereby permitting the use of boats, snow machines, and airplanes. No mention of horsepower size was made; therefore, because of the fragile soils and tundra vegetation, some problems with camping, access points, and trail heads are occurring and more are anticipated. We are undoubtedly going to need assistance to determine the effect of such uses on these areas. This is true for all lands, not just wilderness.

There is a general lack of a code of ethics, and many Alaskans are not sensitive to what they have, as many still have a frontier philosophy. It might also be noted that whenever added restrictions on the land are imposed, the administering agency must have capability of enforcement or the whole thing becomes a farce.

SCIENCE CAN HELP

The scientific community can help by being aware of the problems and issues and assisting with solutions. As Dick Smith pointed out earlier in the conference, all the research in the world will not solve problems unless there is an acceptance by the public to make changes in land use or recreation use. Many solutions will end up in a political arena, and input or assistance from a number of people or organizations will be needed.

In summary, wilderness problems or problems in wilderness must be elevated as high priorities of agencies, then dollars will be made available for solution. We have heard many problems and research needs discussed here today, but all the data or information obtained are not worth a hill of beans if agencies do not use them to implement changes. We also have heard the old excuse by some agency people that they cannot do something because of a lack of funds. If priorities are high enough in any organization, they can usually find a way to get them funded.

AUTHOR

Marvin L. Plenert
Deputy Assistant Regional Director
Wildlife Resources
Fish and Wildlife Service
U.S. Department of the Interior
Denver, CO 80225

SIX CATEGORIES OF NEEDED WILDERNESS RESEARCH

Joyce M. Kelly

Before I begin my remarks I would like to take the opportunity to thank the research community for the assistance and advice it gave freely to the Bureau of Land Management while I was there as Chief of the Wilderness and Recreation Program.

Over the past few days we have heard what's happening in the wilderness research arena and what additional needs exist. I would simply like to highlight a few areas that I believe need special attention.

LIMITS OF ACCEPTABLE CHANGE

Each State office (BLM) or region (Forest Service) should be encouraged to do a Limits of Acceptable Change (LAC) pilot project for at least one wilderness to demonstrate the effectiveness and utility of the concept. This would facilitate setting management guidelines for other wildernesses in the State or Region and would aid in setting thresholds for where and what kind of action was required.

The concern I am expressing here is that if there is only a single pilot project, or several, then the likelihood of adaptability by other States or Regions is limited simply because the strategy may not translate. Thus, the concept may be prematurely rejected simply because the geography and site are so different. For example, a LAC model in Aravaipa Canyon, AZ, has limited applicability to Bear Trap Canyon, MT.

COST OF MANAGEMENT

Unless assessments are available as to what it costs to manage an area, there will be little real incentive to look at more cost-effective management strategies. Studies of cost-effective management schemes and strategies would be a major step forward in helping eliminate administrative limitations and those restrictions that may be inherent in the law.

Basically, this is a data problem where there has been little detailed site management information available. It's also an area where the Federal agencies are often reluctant to have others investigate. An analysis we did of a wilderness management contract in Eagle Cap Wilderness suggested some real opportunities for cost savings to the Forest Service. While there was a concern over expanding this concept because an agency may not always find an appropriately committed contractor, I believe it is important to investigate these opportunities to determine their constraints and possible applicability on a wider scale.

IMPACT OF FEES

We are all aware of the growing concern and discussion about the need to increase user fees. This has been a major push by the Administration, which is not surprising in light of the growing Federal deficit.

The question I would like to put on the table is: How much revenue can an area be expected to generate? And more important, should it be expected to generate a certain level? Should we be viewing wildernesses or recreation areas as true revenue generators? Are these areas truly capable of providing a net revenue source to the U.S. Treasury once you assess the costs of implementation, and administrative overhead?

Or are user fees really a management tool to control and direct use, an offset to management costs, a way of averting more decline in recreation budgets, a way of communicating with the public that these areas need financial assistance? I don't think it has been clear what the objectives of user fees, excise taxes on equipment, and other charges are. Some clear analysis is needed before policies are developed in this area that create expectations that can never be fulfilled.

LAW ENFORCEMENT ISSUES

As a first step in resolving law enforcement issues, we need to define what legal research is needed on what issues. What is the nature of the violations, how successful are the prosecutions, what are the constraints to more successful prosecution?

In wildernesses, enforcement is limited to patrol by plane or by foot or horseback. This obviously imposes practical limitations. The tools of the enforcer are restricted, yet the tools of the violator are not. Are there management tools available that we haven't explored? Considering this area raises questions of whether unique resources which need special protection, for example, endangered species, archeological resources, paleontological resources, should be included in wildernesses. This is an issue that is often raised in debates on wilderness allocation and one that needs to be addressed.

How can civil penalties be made more effective and used for their deterrent value? Civil penalties are considered more desirable by the Government because the Government needs only to prove a "preponderance of evidence" versus "beyond reasonable doubt"—the criminal case requirement. In the latter case, the accused has more "outs" and generally will end up with nothing more than a misdemeanor.

Another problem in the legal arena is how to evaluate damages. The Federal Land Policy Management Act provides for fines up to $2,000 and up to a year in jail; it requires nothing in terms of rehabilitating the resource. We often lack the most rudimentary information necessary to value the resource that has been damaged. Another question here is who makes the value determination? Should the violator participate in setting the value of the resource damaged?

Which enforcement penalties work and which ones don't? What do we know about our successes and failures? Are there discentives which could be created through the legal system? Are there tools which could be used and aren't?

FAILURE—CAN WE LEARN FROM IT?

All too often failure or lack of success in research and management is seen as information we should bury, when we should be viewing it as contributing to our knowledge and understanding and treating it accordingly. Failure should be seen as an instructive learning device and shared. Instead we tend to hide results when they don't verify or validate our expected results.

Rather, failure should be seen as a source of knowledge that can help. To fear revealing unexpected outcomes only stifles creativity and experimentation, and causes needless repetition by others. We need to share our incomplete successes or failures as well as our successes.

BLM LANDS—A NEGLECTED RESOURCE

Not surprisingly, the focus of the wilderness allocation effort and the wilderness management effort has been on protecting wilderness that has trees and trails.

We saw from the presentations yesterday that one of the great remaining wilderness areas in this country is in the Great Basin—in many of the areas managed by the BLM. We were also told these are the areas where there is the greatest paucity of information.

The BLM lands represent a unique resource, which may in fact be much more fragile than the forest, with longer term impacts and more difficult reclamation. These lands have different use patterns due in part to lack of control of access. Therefore, they also have different management needs and different resource protection needs. Most research done which is applicable to these areas deals with off-road vehicle problems and impacts. A critical management question is how to direct the user away from a sensitive resource where there are no trails, no control over access, and no physical barriers.

What this means is that we need to assess what constitutes primitive desert recreation, its use, the impact of use, indicators of overuse, and distribution of use. These resources need attention from the research community as well as from the public. The research community can help raise the consciousness of the public to these issues as well.

Now the final challenge. 1991 is fast approaching—the year that signals the close of the BLM wilderness study process. That leaves very little time for basic research into use patterns on those last remaining "wildlands" identified by Rod Nash yesterday. But there is ample time and opportunity for us to test the thesis that these remaining wildlands can be brought into the wilderness system because of their esthetic, psychological, humanistic, and cultural values.

The challenge is to you, Rod, and others who believe strongly that these are the correct arguments, to enter into the wilderness debate now occurring in the deserts of California, the Great Basin of Idaho and Nevada, the canyons of Utah, and the deserts of New Mexico. The BLM wilderness coordinators on the front lines need articulate spokesmen now, as the boundaries of the study areas are being whittled away.

History is written in the present. I don't want to read in the next edition of **Wilderness and the American Mind** that these desert wildlands were lost because the wrong arguments—recreation, economics, scenery, and the future—were made by the bureaucrats. I want to read how you, Rod, and others helped win the battle and prove the merits of these historical values.

The ball is in your court. Will you accept the challenge?

AUTHOR

Joyce M. Kelly
Water Program Operations
U.S. Environmental Protection Agency
Washington, DC 20460

NATIONAL WILDERNESS RESEARCH CONFERENCE HIGHLIGHTS

Paul C. Pritchard

I am honored and challenged to be given the task of summarizing this conference. To do this, I will divide my comments in three sections. First, I would like to talk about what I think wilderness research is. Second, I would like to talk about what I think the needs are for research based upon your comments. And third, I'd like to talk about the experience of the conference itself.

"What is wilderness research?" That, of course, is comprised of two questions. The first question is "What is research?" From my perspective, and as my good friend Lynn Greenwalt summarized, research is giving meaningful thought to an issue. In this case, the critical term to you as professionals and to you as managers is "meaningful" from a personal fulfillment standpoint—to you as professionals, you as managers—but it must also be meaningful from a social value standpoint.

"What is wilderness?" It is, in fact, a social issue, a social movement; and, therefore, we cannot separate those two definitions nor should we try to do so. Nash pointed out that we would be negligent if we tried to talk about the sciences separated from the humanities and arts. All sections of our society relate to and we hope benefit in varying degrees from research. Lucas went back to the 1880's and talked about research and history moving up to Leopold, the ORRC Commission, the Park Service, the Fish and Wildlife Service, and, of course, the Forest Service's fine job. He talked about what research is as it relates to wilderness. Roy Feuchter pointed out that wilderness comprises areas of great magnitude. For example, 112 of the 122 units of the National Forest System have wilderness in them, and these will grow in number and size. Driver talked about seven benefits. I won't summarize those, but I thought it was interesting that he moved all the way from the concept of knowledge for knowledge sake, to the whole concept of optimizing management.

DEFINITION STILL NEEDED

But in this "age of chips, chips, and chips," of computer chips, of wood chips, and fish and chips, it seems to me what we really need to deal with is the question of the definition of wilderness. We really have only begun to address the issue as I think we probably should. Before the meeting I asked a friend of mine, who as a Biblical scholar has been looking at cultural references we have to "wilderness," to give me some idea of what wilderness is from that perspective. He wrote me a note and I would like to share a few of his comments at this time. He said, "The city represents a world created by us humans—where we seem to be pretty much in charge of things—where things are more or less predictable, orderly, traditional, rational. In wilderness, life is not rational or ordered in the traditional way of thinking. It is the realm of the imagination, of intuition, of symbols. In the wilderness the people of Israel learned to trust God for their survival and to live one day at a time without knowing what the next day would bring. Our lives today are not far from the days of the Old Testament with political upheavals, social unrest, and the potential of nuclear war." He went on to say, "Most of our people spend most of their time living in the city. But periodically the wilderness invades their lives in the form of some crisis or transformation where they discover afresh that we really are not in control." In conclusion he said, "We can only be helpful to people in those wilderness times if we learn to be at home in the wilderness."

People like Thoreau and Emerson have been saying to us that the wilderness represents a great opportunity for us. And that's what I think we are looking at in this conference. We need to step back and realize that we are, in fact, dealing with a much broader social issue—something out of our heritage, our culture, going back not only to Europe but to the very foundation of the Judeo-Christian ethic.

NEEDS HIGHLIGHTS

The second point is what are the needs in research. I thought the panel did an excellent job of summarizing the needs, but let me see if I can highlight just a few points that I thought were important. In talking about six research needs, McCool mentioned the need to look at the effectiveness of tools. That is something that we are very concerned about at the National Parks and Conservation Association (NPCA) because we base our legislative work on good science. We pride ourselves on being accurate; therefore, we depend on you to conduct research to give us accurate information which will have standing before Congress. McCool also mentioned the need for management of biophysical impacts and consequences of use. The conflicts aspect was brought up by Schreyer, Stankey, and Nash. Schreyer mentioned the four most common motives of visitors to wilderness areas—to have social interaction, to experience nature, to escape from our world, and to experience solitude. Nash noted those core defenses are weak, that is to say wilderness is important in order to protect scenic beauty, for economic reasons, for recreation benefits, for water/air quality, or protecting the wilderness for future generations. We have also heard about the need to be careful of how we phrase ourselves (be we managers, researchers, or advocates) when we are talking about research. Both Mott and Bob Howard emphasized the importance of gene pools and the lack of attention that we seem to be giving to this very important worldwide issue. Harold Eidsvik brought up a very enlightening point on how the philosophy of wilderness seems to be getting worldwide acceptance, but the tools and the management schemes are not. And I think that is an important challenge for us if we want to work at the international level.

While addressing the needs for research, Davis talked about three very important points. He said we need to have a better definition of variables, we need to have more focus, and we need to have tighter designs. In the Visitors Impact Management Study (carrying capacity study) that we are working on at NPCA, his points definitely apply as we put together that synthesis document.

All of this brings us back to the point: we really don't have a philosophy of wilderness and it's something those of us in the advocacy realm should take on seriously. But advocacy depends on good science and therefore on good research. And it begins to take shape at meetings like this as we thrash out the important role of research itself. We need to develop a clear attitude, a commitment, and a philosophy (as Kilgore and others pointed out) toward such critical issues as fire management, the emergency use of vehicles, the grazing issues, and the allowable uses of wilderness about which BLM Director Burford talked. However, we also need to develop baseline data and the indicators that are so crucial to good science, good research, and good management.

AN IMPRESSIVE EXPERIENCE

Well, that brings me to my third and final point. I would summarize the experience of the conference by saying how impressive it has been to be here for some 40 hours listening to 56 speakers, interacting with 400 participants, and hearing innumerable and invaluable comments. It's been exciting and stimulating to share this experience with representatives from Taiwan, Scotland, Canada, the United States, and elsewhere, with advocates from the Sierra Club, from the National Wildlife Federation, and other fine groups. Something has been missing, though. We haven't had the young and the old; we haven't had the traditional minorities; we haven't had the new emerging minorities. Those are groups we need to think about because they need to hear their concerns voiced as well in meetings like this. But the interaction has been invaluable and is irreplaceable in terms of the discovery of new knowledge and the social interaction of meeting new friends and people that we have known of or heard about but have not had a chance to work with.

A very positive result of the conference has been the formation of the Wilderness Research Foundation. I would like to share two objectives that I heard at the board meeting the other night. One is the realization that wilderness and the other aspects of our society—our art, our culture—are all inextricably interrelated. We must deal with that, accept that, and seek ways of bringing about that wonderful opportunity such as through wilderness art. But more important, a very strong commitment was made to begin the process of building support, testimony, and in other ways to get the budgets for research increased in the Federal agencies. That challenge will be a very important outgrowth of this particular conference and for the Wilderness Research Foundation.

ALL ARE ADVOCATES

I think it's critical that we realize we can't wait for Washington—that we are all advocates in some way. All of us are advocates for the importance of qualitative research that only you as managers and researchers can bring about. It's crucial that we realize that. You are, in fact, advocates like I am at NPCA. You must consider yourself advocates because without that advocacy role we lose the genius and the commitment that was shown by those people that I mentioned earlier. The people—like Marshall, Olmstead, Thoreau, and others—who blazed this trail before us. It is essential we understand that we are not just at the beginning of a realization, but that it has been evolving for generations. Everything is connected to everything else; in wilderness is the preservation of the universe, of the world, of life, and of our very existence. It seems to me that is what we are really talking about. That is the perspective with which we have to go away from here.

On behalf of the coordinators, the sponsors, and all the people here, I leave the thought that you will go forward and live a happy and fruitful life in wilderness.

AUTHOR

Paul C. Pritchard
President
National Parks and Conservation Association
Washington, DC 20009

☆U.S. GOVERNMENT PRINTING OFFICE:1987 -773 -039/ 61001

Lucas, Robert C., compiler. 1987. Proceedings—national wilderness research conference: issues, state-of-knowledge, future directions; 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 369 p.

Includes 35 reports giving perspectives on wilderness values, management, and research; states-of-knowledge for wilderness resource research; states-of-knowledge for wilderness user research; and future directions for wilderness research.

KEYWORDS: wilderness values, wilderness management, role of fire, air quality, soil and vegetation, fish and wildlife, water resources, wilderness use

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

USDA policy prohibits discrimination because of race, color, national origin, sex, age, religion, or handicapping condition. Any person who believes he or she has been discriminated against in any USDA-related activity should immediately contact the Secretary of Agriculture, Washington, DC 20250.

United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

General Technical
Report INT-221

February 1987

Methods for Evaluating Riparian Habitats With Applications to Management

CLEMSON
MAY 27 1987
PUBLIC DOCUMENTS
DEPOSITORY ITEM
CLEMSON
LIBRARY

William S. Platts
Carl Armour
Gordon D. Booth
Mason Bryant
Judith L. Bufford
Paul Cuplin
Sherman Jensen
George W. Lienkaemper
G. Wayne Minshall
Stephen B. Monsen
Rodger L. Nelson
James R. Sedell
Joel S. Tuhy

THE AUTHORS

WILLIAM S. PLATTS is a research fishery biologist for the Intermountain Research Station at Boise, ID. He received a B.S. degree in conservation education in 1955 from Idaho State University, an M.S. degree in fisheries in 1957, and a Ph.D. degree in fisheries in 1972 from Utah State University. From 1962 through 1966, he worked as a regional fishery biologist and supervisor in enforcement with the Idaho Fish and Game Department. From 1966 through 1976, he was the Idaho zone fishery biologist for the USDA Forest Service, Intermountain Region, and consultant to the Surface Environment and Mining (SEAM) program. He has been in his present position since 1976.

CARL ARMOUR is a fishery biologist for the U.S. Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO. He received an M.S. degree in fisheries in 1966 from the University of Massachusetts and a Ph.D. degree in fisheries from the University of Idaho in 1969. Experiences include college teaching (1969-70), postdoctoral work at Texas A. & M. University (1970-71), industrial consulting (1971-75), and assignment as a Bureau of Land Management environmental specialist and fisheries biologist (1975-78). He has been in his present position since 1978. One of his principal interests is environmental perturbation affecting western range streams.

GORDON D. BOOTH is leader of the Statistics and Computer Science Group for the Intermountain Station at Ogden, UT. He received a B.A. degree in 1960 and a B.S. degree in statistics in 1963, both from Brigham Young University. Then he was granted an M.S. degree in 1967 and a Ph.D. degree in 1973, both in statistics and both from Iowa State University. From 1963 to 1965, he worked as consulting statistician with U.S. Steel Corporation and with Phillips Petroleum Co. From 1967 to 1981 he worked as consulting statistician with the Agricultural Research Service, U.S. Department of Agriculture. He has been in his present position since 1981. His main interests are in the application of statistical methods to natural resource problems—especially time series.

MASON BRYANT is a research fishery biologist for the Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station at Juneau, AK. He received a B.A. degree from the University of Vermont in 1967. The following 2 years were spent with the U.S. Army. He received an M.S. degree in zoology in 1972 from the University of Maine in Orono. In 1976 he received a Ph.D. degree from the University of Washington and moved to his present position in Alaska.

JUDITH L. BUFFORD is a biological technician (fisheries) with the Pacific Northwest Research Station in Corvallis, OR. She received a B.A. degree in biology in 1976 from Rollins College, Winter Park, FL, and her M.S. degree in marine biology in 1981 from the University of Miami, FL. She has been in her present position since 1981.

PAUL CUPLIN is a fishery biologist for the Bureau of Land Management, Denver Service Center. He received a B.S. degree in fisheries in 1952 from the University of Washington and an M.S. degree in fisheries from Utah State University in 1961. From 1953 to 1971 he was a fishery research biologist, district fishery biologist, and supervisor of fish hatcheries for Idaho Department of Fish and Game. From 1971 to 1980 he was a fishery biologist at BLM Denver Service Center; during 1979 and 1980 he was assigned to the Branch of Remote Sensing. In 1981 he served as fisheries program leader for the Washington Office of the Bureau of Land Management. He returned to the Denver Service Center in 1982.

SHERMAN JENSEN is a soil scientist/physical ecologist, with B.S. and M.S. degrees from Utah State University. His education included a broad scope of physical and natural sciences with primary emphases on soil and botany. He received additional training from the Soil Conservation Service in 1979. In 1981, he established White Horse Associates, an environmental consulting firm in Logan, UT. His primary professional interests include the classification and evaluation of riparian ecosystems, soil and botanical surveys, inventories and planning for mined land reclamation, and ecological studies of interrelationships between physical and biological components of the environment.

GEORGE W. LIENKAEMPER is a geologist for the Pacific Northwest Research Station in Corvallis, OR. He received a B.S. degree in geology in 1969 and an M.S. degree in interdisciplinary studies in 1976 from the University of Oregon. From 1975 to 1978 he worked on various research projects at Oregon State University including the International Biological Programs and the River Continuum Study. He has been in his present position since 1978.

G. WAYNE MINSHALL is professor of zoology at Idaho State University, Pocatello. He received his B.S. degree in fisheries management in 1961 from Montana State University and his Ph.D. degree in zoology in 1965 from the University of Louisville. He was a North Atlantic Treaty Organization (NATO) postdoctoral fellow at Freshwater Biological Association Windemere Laboratory from 1965 through 1966. He joined the staff at Idaho State University in 1966 where he has pursued a teaching and research career in stream ecology.

STEPHEN B. MONSEN is a botanist at the Intermountain Research Station, located at the Shrub Sciences Laboratory, Provo, UT. He received his B.S. degree from Brigham Young University. He has been involved with plant selection, site preparation, and planting practices of range and wildland sites in Utah and Idaho for approximately 25 years. His research has been directed to the restoration of seriously disturbed rangelands and watershed conditions.

Intermountain Research Station
324 25th Street
Ogden, UT 84401

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

RODGER L. NELSON is a biological technician with the Intermountain Research Station at Boise, ID. He received his B.S. degree in biological sciences from the University of California, Irvine, in 1973, attended graduate school in ecology at the University of California, Davis, and is currently enrolled in the master's in business administration program at Boise State University. Rodger has been with the Intermountain Station since 1978.

JAMES R. SEDELL is a research ecologist with the Pacific Northwest Research Station in Corvallis, OR. He received a B.A. degree in philosophy in 1966 from Willamette University, Salem, OR, and his Ph.D. degree in environmental biology in 1971 from the University of Pittsburgh, PA. He has been in his present position since 1980.

JOEL S. TUHY is currently employed by The Nature Conservancy as its Utah Public Lands Protection Planner. He received a B.S. degree in outdoor recreation resource management in 1977 from Iowa State University and an M.S. degree in forest ecology from the University of Idaho in 1981. During his thesis work, 1978 to 1979 (a valley-bottom community classification in the Sawtooth Valley, ID), he developed the field sampling techniques now generally used for riparian classification in the Intermountain region. He served as principal investigator for riparian classification contracts with the USDA Forest Service in western Wyoming (1980 to 1981) and central Idaho (1981 to 1982). He has been in his present position since 1983.

CONTENTS

Page
Introduction: Riparian Area Evaluation Needs 1
Collection of Riparian Habitat Information 2
  General Field Sampling 2
  Concepts About Populations and Samples 3
  Simple Random Sampling 3
  Stratified Random Sampling 6
  Cluster Sampling 9
  Two-Stage Sampling 11
  Monitoring 14
Measuring Vegetation 17
  Vegetative Use by Animals 17
  Vegetative Overhang 18
  Streambank Stability 19
  Streamside Cover 19
  Electronic Forage Analysis 20
Riparian Community Classification 36
  Field Methods 36
  Office Methods 38
  Final Considerations 38
Riparian Soils 39
  Flood Plain Geomorphology 39
  Soil Genesis 42
  Soil Morphology 42
  Soil Taxonomy 50
  Soil Description 55
  Summary 55
Remote Sensing 55
  Application of Large-Scale Photos for Inventory and Monitoring 56
  Baseline 57
  Ground Data Collection 57
  On-Site Data Collection 57
  Acquisition of Large-Scale Aerial Photographs ... 57
  Monitoring Procedures and Area Management ... 57
  Variables 57
  Sample Size 58
  Results 58
Water Column Measurements 58
  Vegetative Canopy Closure and Density 58
  Light Intensity 60
  Stream Surface Shading From Surrounding Vegetation 61
  Stream Surface Shading From Topographic and Vegetative Features 65
  Solar Heat Inputs Using the Solar Pathfinder™ ... 68
Streambanks 75
  Streambank and Channel Aggradation, Degradation, and Morphology 75
  Streambank Soil Alteration 80
  Streambank Undercut 81
  Stream Shore Water Depth 81
  Stream Channel-Bank Angle 82
Measuring and Mapping Organic Debris 83
  Measuring Woody Debris in Stream Channels ... 83
  Mapping Debris 88
  Measuring Large Woody Debris on Stream Banks 93
Historic Evaluation of Riparian Habitats 93
  Consulting the Historical Record 93
  Interpreting the Records 95
  Problems in Interpretation 95
  Using the Historical Record 98
  Implications to Riparian Research 105
Evaluation of Stream Riparian Area Conditions Using Benthic Macroinvertebrates 105
Planting of Riparian Sites 109
  Factors Influencing Revegetation 110
  Restoration by Natural Means 111
  Site Preparation and Alterations 113
  Seeding Riparian Communities 115
  Plant Selection and Uses 115
  Planting Woody Species 119
References 124
Appendix 1: Statistical Tables 132
Appendix 2: Accuracy, Precision, and Confidence Intervals of Selected Variables 134
Appendix 3: Forms for Recording Hydraulic Geometry and Soil Data 137
Appendix 4: Computer Program for Herbage Phytomass and Utilization Measurements 140
Appendix 5: Flow Chart for HERB-2 163
Appendix 6: Requirements, Example, and Computer Program for Calculating Stream Surface Shading from Topographic and Vegetative Features 164
Appendix 7: Bibliographies, Source Materials, and Repositories for Information on Historical Riparian Conditions 171
Appendix 8: Riparian Types of the Upper Salmon/Middle Fork Salmon River Drainages, Idaho 173
Appendix 9: Riparian Community Types of Eastern Idaho and Western Wyoming 174
Appendix 10: Pool Quality Rating Tables 176

Methods for Evaluating Riparian Habitats With Applications to Management

William S. Platts
Carl Armour
Gordon D. Booth
Mason Bryant
Judith L. Bufford
Paul Cuplin
Sherman Jensen
George W. Lienkaemper
G. Wayne Minshall
Stephen B. Monsen
Rodger L. Nelson
James R. Sedell
Joel S. Tuhy

INTRODUCTION: RIPARIAN AREA EVALUATION NEEDS

Riparian area planning and management is a major national issue today—something that should have been the case a century ago. A century of additive effects of land use has resulted in major impacts on many riparian stream habitats and their fisheries, wildlife, and domestic livestock use. Before scientists can evaluate the influences of various land and water uses on riparian environments, they must first understand these environments. This means being able to detect and measure with confidence the natural and artificial variation and instantaneous conditions of the riparian habitat. These conditions must then be related to the production capability of riparian habitat and any extraneous factors affecting this production potential.

Combined effects of geology, climate, soil, vegetation, flow regimes, and especially human activity, can result in constantly changing riparian habitat conditions. These riparian habitats respond, often dramatically, to management practices that improve their productive capability. Because the riparian component of fish and wildlife habitat can often be manipulated quite quickly, it is often less costly and much easier to immediately benefit a fishery through riparian area rehabilitation than through other stream enhancement activities such as the use of artificial channel flow modification structures.

Land and water managers have inadequate guidelines for determining existing and potential impacts on riparian stream resources in their management programs. Methods that will completely document and monitor riparian ecosystems have not been adequately developed. Therefore, methods need to be constantly refined that will evaluate the productivity of riparian environments and how the stages of this productivity affect the health and survival of the fish and wildlife that depend on it.

Recently there has been an increase in the number of studies evaluating the condition, trend, and potential of riparian habitats with respect to their capability to support life. The success or failure of these studies depends on the precision, accuracy, and comprehensiveness of the data used for interpretation and decision making. This is where the difficulty arises because it is not easy to develop accurate methods that will quantitatively determine the actual or changing states of an ecosystem. Specialists who collect the data must know and be able to dampen those factors that affect the precision and accuracy of their measurements, account for the variability and uncertainties in the data collected, and conduct the study in a manner that will lead to a true answer. Because past measurements can seldom be verified for quality, they must be collected with tested methods using a valid sampling design, followed by proper analysis and interpretation.

Many of the techniques being used today are untested, and some were designed to optimize time rather than accuracy. Difficult decisions, those requiring that data be collected and analyzed over sufficient time, are often being made on inadequate information. Thus, poor resource management decisions will often result. Some of the variables in this report have undergone testing and have their respective precision and accuracy ratings listed.

This report, in combination with Platts and others (1983), is an attempt to compile a comprehensive set of the latest methods for resource specialists to use in managing, evaluating, and monitoring riparian conditions adjacent to streams, lakes, ponds, and reservoirs. The emphasis is on streams. Today's riparian area evaluation methods are far from perfect, and they are not likely to be completely accurate and precise in the near future. Therefore, such methods need constant refinement and new and better techniques need to be developed. We hope this manual hastens the day when riparian evaluation methods will provide the complete mix of data needed for accurate decision making.

COLLECTION OF RIPARIAN HABITAT INFORMATION

General Field Sampling

Information collection is necessary for inventory and monitoring activities associated with riparian management programs. Success for the programs is dependent upon the acquisition and use of information that must be appropriate for planning processes and the design of site-specific management. Unfortunately, widespread problems have resulted in inadequate, improper, or excessive information. This is usually attributed to a poorly thought-out approach to collecting information for specifically fulfilling resource management requirements. Therefore, the objective of this chapter is to present basic guidance for use when field sampling programs are being designed. We have presented information in a section pertaining to a general field sampling program and a second section in which considerations for monitoring approaches are discussed.

Six basic steps should be followed for a field sampling program (fig. 1) if useful information is to be obtained. Before sampling, justification for collecting the information (step 1) must be made. Considerations for establishing justifications include: (1) Is the information already available? (2) Is the acquisition of new information absolutely necessary for activities associated with riparian resource planning and management activities? (3) Would it be possible to measure a substitute condition to obtain essentially the same information at lower cost?

After specific information needs are defined, collection approaches must be determined (step 2). Considerations for this step must include evaluations of the suitability of a technique for achieving appropriate levels of accuracy and precision and the practicality of the technique based on ease of field application, costs, and other factors. Following step 2, pilot sampling (step 3) must be performed. Essentially, this step is a trial run designed to detect and correct problems that could seriously affect sampling. Additionally, this step is necessary for training of field crews and obtaining preliminary data for use in estimating the sample size for a predetermined level of statistical confidence. If problems are detected, which is usually the case (examples: sampling gear performs improperly, inadequate time was allocated for collecting and analyzing samples, more samples must be collected than originally planned), corrective measures must be taken. Step 3 is mandatory because serious flaws in the way sampling is conducted will adversely impact the quality of information that is collected.

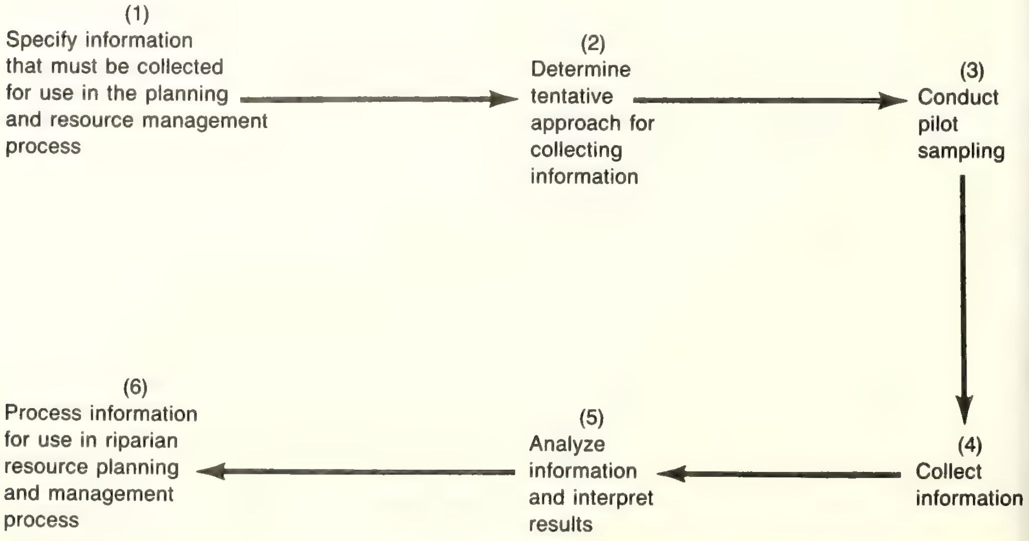

(1)
Specify information that must be collected for use in the planning and resource management process
(2)
Determine tentative approach for collecting information
(3)
Conduct pilot sampling
(4)
Collect information
(5)
Analyze information and interpret results
(6)
Process information for use in riparian resource planning and management process

Figure 1—Steps for a field sampling program to obtain useful information for riparian resource planning and management processes.

When information is collected (step 4), it must be recorded accurately and assembled in a usable format for analyses (step 5). When the results are processed for use in planning and management procedures (step 6), careful thought must be given to the best way to present it to resource specialists and administrators. If the information is not presented with clarity and in a useful form, effort and costs expended for the work will be wasted.

Concepts About Populations and Samples

The entire collection of items in which we are interested is called the population. For example, the population might be a 100-ft section of the stream to be divided into 100 cross sections of 1 ft each. If we take measurements on only 20 of these cross sections, the cross sections we measure constitute the sample. The whole purpose of using sampling is to obtain information about the entire population when it is not possible or feasible to measure every element in it. We hope the items in the sample will give us accurate information about the whole population.

Populations can be either finite (with a fixed, countable number of elements) or infinite (with an infinite number of elements). Some populations are technically finite but with so many elements we could not reasonably count them. Such populations are considered to be infinite.

To illustrate, consider the example mentioned above. The 100-ft stretch of stream is the population. We have arbitrarily divided it into 100 cross sections of 1 ft each. Does this mean we have 100 elements in our population? Not necessarily. If we are interested in some characteristic that requires measurement over the entire 1-ft cross section, then the population could be considered finite with 100 elements in it. On the other hand, if we were interested in a characteristic that requires measurement at only a point along the stream (such as stream width measured at a transect), it would be incorrect to consider the population as consisting of only 100 elements. In this case the population should be dealt with as infinite.

The methods that follow will often involve the finite population correction (*fpc*). It is defined as:

$$fpc = (1 - n/N)$$

where:

N = number of elements in the whole population

n = number of elements in the sample.

Notice that if N is large (essentially infinite), the *fpc* approaches 1. In the methods described later, if the population is infinite, we can ignore the *fpc* (that is, consider it equal to 1). This is true because the *fpc* is always used as a multiplier and multiplying by 1 has no effect.

We use "error of estimation" to denote the distance by which our estimate misses the true population value we are attempting to estimate. Although we cannot know the true error of estimation, it would be useful to be quite certain that after our sampling and estimating are complete, we have an error of estimation that is no greater than some upper bound, say B. We will present some statistical methods designed to help us determine how large our sample must be to accomplish this.

Common field sampling procedures are simple random sampling, stratified random sampling, and cluster sampling (table 1). Most of the following computational examples for the procedures were adapted from Scheaffer and others (1979). The information presented here is expected to introduce field workers to some useful procedures; prior to application, a qualified statistician should be consulted.

Simple Random Sampling

A simple random sample (SRS) is, as its name implies, the sampling method that is simplest in concept. For its use, each element in the population (such as plots and transects) must be identifiable as individuals. Sampling must be performed in such a way that every element in the population has the same probability of being in the sample.

Using simple random sampling often results in samples that (1) are widely dispersed, causing considerable travel expense, and (2) leave some areas totally unsampled. Therefore, the most successful use of SRS is in relatively small geographical areas where a degree of homogeneity is known to exist. Simple random sampling could be used in other circumstances, but it would tend to be inefficient and more costly.

Simple random sampling should probably be within ecological types instead of across multiple types. This precaution will tend to reduce the variability and increase the precision of habitat parameter estimates. The precaution is reasonable, for example, when one considers the high variation that occurs between riparian habitat in meadows compared to headwater-timbered areas in an allotment that is heavily grazed.

Table 1—Comparison of simple random, stratified random, and cluster sampling techniques

Sampling approach	Total number of elements or plots (potential samples) in population must be known in advance?	Key features	Application considerations	Appropriate field use
Simple random	Yes - identification of all elements or plots necessary for selection of random sample.	Through random sampling there is an equal chance for sampling of each element. This helps insure that data representative of an overall population will be obtained.	Excessive costs can be incurred if elements are widely scattered through a large geographic area.	Randomly distributed populations in relatively small geographic areas.
Stratified random	Yes - after strata are defined, elements or plots within each stratum are selected randomly for sampling.	Advantages over simple random sampling can be reduced and variance for parameter estimators and costs can be reduced substantially if sampling is restricted to a smaller geographic area. Additionally, conditions between strata can be compared statistically, that is, difference among means.	Within each stratum there must be relative homogeneity and heterogeneity must be maximized among strata. Homogeneity within helps to reduce sample variance.	Populations in homogeneous strata dissimilar from other strata. Recommended if sampling is conducted in recognizable homogeneous strata.
Cluster sampling	All elements are sampled for one-stage sampling. Two-stage sampling requires advance identification of elements for random selection for sampling.	Clusters to sample are selected randomly. Clusters must be alike (homogeneous between) with heterogeneous conditions within.	The sampling approach can be economical because heterogeneity within clusters helps to lower overall sampling costs because travel distance and time can be lessened when a representative sample is obtained. Clusters must have the same number of sampling units to avoid more complicated computations. Two-stage analysis is appropriate when there are too many elements per cluster to sample, or the elements are so similar that counting all of them is wasteful. Prior to using cluster sampling, a statistician should always be consulted.	Populations that are associated with heterogeneous conditions for which ordered, systematic sampling, simple random and stratified sampling is infeasible **and** there are an adequate number of clusters to sample.

Example 1—Twenty transects ($n = 20$) are placed along a stream in a meadow. They are selected randomly, and stream width is measured at each transect. What are the mean width, the upper bound on the error of estimation (in this case, B), and the 95 percent confidence interval on the population mean (μ)? Assuming that the information is preliminary, how many samples would have to be collected to be reasonably sure B does not exceed 1.07 ft?

Step 1 - Calculate the sample mean and variance of the following 20 measurements on stream width: 10, 16, 11, 8, 9, 11, 3, 13, 10, 7, 5, 12, 9, 12, 11, 20, 11, 12, 14, 10.

NOTE: Almost any scientific calculator has the built-in capability of computing both the mean ($\bar{X}$) and the standard deviation (s) or the variance (s^2). If your calculator computes the standard deviation, the variance is obtained by squaring the standard deviation.

In this case we obtain $\bar{X} = 10.7000$, $s^2 = 13.4843$.

Step 2 - Calculate the bound on the error of estimation (B)

$$B = 1.96 \sqrt{\frac{s^2}{n} \frac{N-n}{N}}$$

In this case, the population is infinite and the *fpc* = 1. Therefore:

$$B = 1.96 \sqrt{\frac{13.4843}{20}} = 1.96 \sqrt{0.6742} = 1.6094$$

where:

$\frac{N-n}{N}$ = the finite population correction (*fpc*)

1.96 = Z value from the normal distribution (see appendix 1) for the 95 percent level. If another level of confidence were used, the number 1.96 would be replaced by the appropriate value from the normal distribution.

Step 3 - Calculate the 95 percent confidence interval for the population mean (μ).

The interval is computed as:

Lower limit = $\bar{X} - B = 10.7000 - 1.6094 = 9.0906$

Upper limit = $\bar{X} + B = 10.7000 + 1.6094 = 12.3094$.

This means we are quite confident (95 percent) that the true population mean is between 9.0906 and 12.3094.

Step 4 - Calculate n' = estimated sample size if B is not to exceed 1.07 ft

$$n' = \frac{(Z^2)(s^2)}{B^2}$$

$$= \frac{(1.96)^2 (13.4843)}{(1.07)^2} = 45.2453$$

We always round to the next higher number. Therefore:

$n' = 46$

where:

$Z = 1.96$ at the 95 percent confidence level (see appendix 1).

A sample size of $n = 46$ should give us a good chance of obtaining $B \leqslant 1.07$ ft.

Example 2—An inventory was conducted along a 60-mile stretch of a stream. Each 1-mile segment ($N = 60$) was designated as a possible sample site, and 20 sites ($n = 20$) were randomly selected for sampling along both sides of the stream to a distance of 200 ft back from each bank. Snag trees in each sample site were counted. There was an average of 10 trees ($\bar{X}$) per site with a sample variance (s^2) of 8.3731. Estimate the total number of snags in the 60-mile stretch, the bound on the error of estimation (B), the 95 percent confidence interval for the total number of snags in the population, and the estimated sample size if our estimate is to be within 25 snags of the true total.

In this case, each 1-mile segment was a potential sample site and, if chosen for the sample, would be studied in its entirety—not at a single point. This population can be considered finite with $N = 60$. (Of course, we might have chosen to use 120 segments of 0.5 mile each for a finite population of $N = 120$.)

Step 1 - Calculate $\hat{\tau}$, the estimate of the total number of snags in the 60-mile stretch

$$\hat{\tau} = N\bar{X} = (60)\,(10) = 600 \text{ snag trees}$$

Step 2 - Calculate the estimated variance of $\hat{\tau}$

$$\hat{V}(\hat{\tau}) = N^2\left(\frac{s^2}{n}\right)\left(\frac{N-n}{N}\right) = 60^2\left(\frac{8.3731}{20}\right)\left(\frac{60-20}{60}\right)$$

$$= (3{,}600)(0.4187)(0.6667) = 1{,}004.77$$

Step 3 - Calculate the bound on the error of estimation

$$B = (1.96)\sqrt{\hat{V}(\hat{\tau})}$$

$$= (1.96)\sqrt{1{,}004.77} = 62.1284$$

where:

$1.96 = Z$ for the 95 percent confidence level.

Step 4 - Calculate the 95 percent confidence interval for the total number of snag trees in the population

The interval is computed as:

Lower limit $= \hat{\tau} - B = 600 - 62.1284 = 537.9$

Upper limit $= \hat{\tau} + B = 600 + 62.1284 = 662.1.$

Step 5 - Calculate n', the estimated sample size for B not to exceed 25 snags

$$n' = \frac{NS^2}{(N-1)D + S^2}$$

where:

$$D = \frac{B^2}{Z^2N^2}$$

$$= \frac{(25)^2}{(1.96)^2(60)^2} = 0.0452$$

$$n' = \frac{(60)(8.3731)}{(60\text{-}1)(0.0452) + 8.3731} = 45.5$$

Rounding up gives $n' = 46$.

Therefore, a sample of $n = 46$ should give us high probability of estimating the true number of snags within 25 trees.

Stratified Random Sampling

If the population of interest falls naturally into several subdivisions, or strata, stratified random sampling is found to be substantially more efficient than simple random sampling. For example, if the number of shrubs is a management concern in a riparian zone that extends through several homogeneous vegetation types (such as sagebrush, sagebrush-grass, and ponderosa pine-Idaho fescue), this method of sampling is suitable. This procedure requires that the investigator clearly identify each stratum in advance of sampling. Then a simple random sample (SRS) is taken independently within each stratum.

In addition to being more efficient in estimating the overall population mean or total, stratified random sampling provides separate estimates for each stratum. This feature alone might be reason enough for using this method over SRS.

Example 3—Assuming that the following information is collected from three strata, what are the mean number of shrubs per acre, the bound (B) on the error of estimation, and the 95 percent confidence interval for the population mean (μ)? Sample means and variances were calculated for each stratum. Approximately 13 percent of the acres were sampled in each stratum. This is a finite population with three strata such that $N_1 = 155$, $N_2 = 62$, and $N_3 = 93$.

Stratum	Total acres/ stratum (N_h)	Total acres sampled (n_h)	Sample stratum mean $\bar{X}_h$	Total shrubs $N_h\bar{X}_h$	Stratum variance s_h^2	$N_h s_h^2$
1 Sagebrush	155	20	33.900	5,254.500	35.358	5,480.49
2 Sagebrush-grass	62	8	25.125	1,557.750	232.411	14,409.48
3 Ponderosa pine-Idaho Fescue	93	12	19.000	1,767.000	87.636	8,150.15
	310	40		8,578.750		28,040.12

$N = \Sigma N_h = 310$ $\quad n = \Sigma n_h = 40$ $\quad T = \Sigma N_h \bar{X}_h = 8{,}578.750$ $\quad s^2 = \Sigma N_h s_h^2 = 28{,}040.12$

Step 1 - Calculate sample mean

$$\bar{X}_{st} = \frac{T}{N}$$

$$= \frac{8{,}578.750}{310} = 27.673$$

= sample estimate of μ, the population mean number of shrubs per acre

Step 2 - Calculate an estimate of the variance of $\bar{X}_{st}$

$$\hat{V}(\bar{X}_{st}) = \frac{1}{N^2} \Sigma \left[N_h^2 \left(\frac{N_h - n_h}{N_h}\right) \left(\frac{s_h^2}{n_h}\right) \right]$$

$$= \frac{1}{(310)^2} \left[(155)^2 \left(\frac{(155 - 20)}{155}\right) \left(\frac{35.358}{20}\right) + (62)^2 \left(\frac{(62 - 8)}{62}\right) \left(\frac{(232.411)}{8}\right) + (93)^2 \left(\frac{(93 - 12)}{93}\right) \left(\frac{(87.636)}{12}\right) \right]$$

$$= \frac{1}{(310)^2} (36{,}993.308 + 97{,}264.004 + 55{,}013.499)$$

$$= \frac{189{,}270.81}{96{,}100} = 1.970$$

Step 3 - Calculate the bound on the error of estimation and the 95 percent confidence interval

$$B = (1.96) \sqrt{\hat{V}(\bar{X}_{st})} = (1.96) \sqrt{1.970} = 2.751$$

Step 4 - Calculate the 95 percent confidence interval for the population mean (μ) number of shrubs per acre

The interval is calculated as:

Lower limit: $\bar{X}_{st} - B = 27.673 - 2.751 = 24.922$

Upper limit: $\bar{X}_{st} + B = 27.673 + 2.751 = 30.424$.

Example 4—What should the sample size be for each stratum if we want to be 95 percent confident that the error of estimation has a bound (B) no larger than 2.0?

Step 1 - Calculate the denominator for stratum weights

$$\text{Denominator} = \Sigma N_h S_h$$

$$= (155) \sqrt{35.358} + (62) \sqrt{232.411} + (93) \sqrt{87.636}$$

$$= 921.67 + 945.19 + 870.61$$

$$= 2{,}737.47$$

Step 2 - Calculate the stratum weights

$$w_h = \frac{N_h s_h}{\Sigma N_h s_h}$$

$= $ the proportion of the total sample size, n, that will come from stratum h.

$$w_1 = \frac{921.67}{2{,}737.47} = 0.337$$

$$w_2 = \frac{945.19}{2{,}737.393} = 0.345$$

$$w_3 = \frac{870.573}{2{,}737.393} = 0.318$$

Notice that the weights over all three strata add up to 1.000. To determine the size of sample required from stratum h, multiply the total sample size by w_h. Therefore,

$$n_h = w_h n.$$

We still need to determine the overall sample size, n.

Step 3 - Calculate the numerator for the n' equation

$$\text{Numerator} = \Sigma \frac{N_h^2 s_h^2}{w_h}$$

$$= \frac{(155)^2(35.358)}{0.337} + \frac{(62)^2(232.411)}{0.345} + \frac{(93)^2(87.636)}{0.318}$$

$$= 2{,}520{,}700.148 + 2{,}589{,}530.099 + 2{,}383{,}533.849$$

$$= 7{,}493{,}764.096$$

Step 4 - Calculate n'

$$D = \frac{B^2}{Z^2} = \frac{(2.0)^2}{(1.96)^2}$$

$= 1.041$, where $Z = 1.96$ comes from the normal distribution (appendix 1).

Finally

$$n' = \frac{\text{Numerator}}{N^2 D + s^2}$$

$$= \frac{7{,}493{,}764.096}{(310)^2(1.041) + 28{,}040.12} = \frac{7{,}493{,}764.096}{100{,}040.10 + 28{,}040.12}$$

$$= \frac{7{,}493{,}764.096}{128{,}080.22} = 58.508 \text{ or } 59$$

Therefore, an overall sample of $n = 59$ should give the investigator high probability of obtaining an estimate that is no more than 2.0 shrubs per acre from the population mean being estimated.

Step 5 - Calculate sample size for each stratum

$n_1 = w_1 n' = (0.337)(59) = 19.883$ or 20

$n_2 = w_2 n' = (0.345)(59) = 20.355$ or 20

$n_3 = w_3 n' = (0.318)(59) = 18.762$ or 19

Total 59

NOTE: The weights, w_h, were determined in such a way that the variance of $\bar{X}_{st}$ is minimized for a fixed value of n. Therefore, once we determined an estimate of n, say n', we applied the weights to it to obtain the sample size in each stratum.

Example 5—Using the results of example 4, what is the estimate of the total number of shrubs in the three strata, the bounds on the error of estimation (B), the 95 percent confidence interval for the estimate, and the estimated number of samples that would have to be collected for B not to exceed 400 shrubs?

Step 1 - Calculate the value for $\hat{\tau}$, the estimate of the population total number of shrubs

$$\hat{\tau} = N\bar{X}_{st} = (310)(27.673) = 8{,}578.630 \text{ shrubs}$$

Step 2 - Calculate the estimated variance of $\hat{\tau}$

$$\hat{V}(N\bar{X}_{st}) = N^2\hat{V}(\bar{X}_{st}) = (310)^2(1.970) = 189{,}317$$

Step 3 - Calculate the bounds on the error of estimation

$$B = 1.96\sqrt{\hat{V}(N\bar{X}_{st})} = 1.96\sqrt{189{,}317} = 852.81$$

NOTE: Although the same symbol (B) is used in examples 4 and 5, its value is different for the mean (μ) than for the total (τ).

Step 4 - Calculate the 95 percent confidence interval for the total number of shrubs in the population

The interval is computed as:

Lower limit: $\hat{\tau}_{st} - B = 8{,}578.63 - 852.81 = 7{,}725.82$

Upper limit: $\hat{\tau}_{st} + B = 8{,}578.63 + 852.81 = 9{,}431.44$.

Step 5 - Calculate n', the estimated sample size for B not to exceed 400 shrubs

The only difference between this case and the estimation of μ in example 4 is in the computation of D. We now have

$$D = \frac{B^2}{Z^2N^2} = \frac{(400)^2}{(1.96)^2(310)^2} = 0.433$$

where Z is from a table of the normal distribution (appendix 1) for 95 percent confidence.

$$n' = \frac{\text{Numerator}}{N^2D + s^2} = \frac{7{,}493{,}764.096}{(310)^2(0.433) + 28{,}040.12} = \frac{7{,}509{,}992.786}{69{,}651.420} = 107.59 \text{ or } 108 \text{ rounded up}$$

We can apply the weights from example 4 to obtain the sample sizes for each stratum. We get

$$n_1 = (0.337)\ 108 = 36.40 \text{ or } 36$$

$$n_2 = (0.345)\ 108 = 37.26 \text{ or } 37$$

$$n_3 = (0.318)\ 108 = 34.34 \text{ or } 34$$

Cluster Sampling

Cluster sampling should not be confused with cluster analysis, which is a classification and taxonomic technique. Here, cluster sampling refers to a method of collecting a sample when the individual elements cannot be identified in advance. Instead, we are only able to identify groups or clusters of these elements. A sample of the clusters is then obtained, and every element in each cluster is measured.

For example, we may wish to take measurements on individual trees in a riparian area but are only able to identify 1-acre plots along the stream. Each plot can contain a different number of trees, and the individual trees cannot be identified before taking the sample. Cluster sampling allows us to select a sample of clusters, instead of individual trees. We would then measure every tree within each cluster.

Cluster sampling is convenient and inexpensive with regard to travel costs. To gain maximum advantage of this method, elements within a cluster should be close to each other geographically.

If we compare cluster sampling with either simple random sampling or stratified random sampling, we find one major advantage of the cluster method: the cost per element sampled is lower than for the other two methods. Unfortunately, two disadvantages of cluster sampling are: (1) the variance among elements sampled tends to be higher, and (2) the computations required to analyze the results of the sample are more extensive. Therefore, cluster sampling is preferable to the other methods if the cost benefits exceed the disadvantages.

If we have only a few clusters, each quite large, we minimize our costs—especially of travel. However, samples with only a few clusters produce estimates with low precision (that is, high variance). On the other hand, if we increase the number of clusters (making each cluster smaller), the variance is reduced while the cost is increased. The user must find a compromise.

Whether sampling 40 clusters of 0.5 acre each is better than 20 clusters of a full acre each is not clear, although approximately the same number of trees may be measured with either sample. There would be a larger number of the smaller clusters, and therefore they would be dispersed more evenly over the population. The estimates produced would have lower variability than those from fewer but larger clusters. However, the sampler would have to travel to twice as many sites, thus increasing costs. Knowledge of the variability and costs involved would be the key to planning such a study effectively.

Example 6—Suppose that we have 30 clusters of 1 acre each ($N = 30$) in a riparian area. Calculate the average number of cavities per snag tree, the bound on the error of estimation (B), and the 95 percent confidence interval for the population mean (μ). Five clusters (n) are selected for sampling and data are collected for all snag trees in each cluster. Sampling data are tabulated below.

Cluster	**Number of snag trees (m_i)**	**Total cavities (X_i)**
1	8	5
2	9	7
3	4	8
4	5	9
5	6	10
	$\Sigma m_i = 32$	$\Sigma X_i = 39$

Step 1 - Calculate an estimate of μ, the population mean, for cavities per snag tree

$$\bar{X} = \frac{\Sigma X_i}{\Sigma m_i} = \frac{39}{32} = 1.22 \text{ cavities per snag tree}$$

Step 2 - Calculate $\bar{m}$, the average cluster size for the sample

$$\bar{m} = \frac{\Sigma m_i}{n} = \frac{32}{5} = 6.4 \text{ snag trees per cluster}$$

An estimate of the total number of snag trees in the 30 clusters is $N\bar{m} = (30)(6.4) = 192.0$ trees.

Step 3 - Calculate sum of squares

Cluster	**m_i**	**X_i**	**$\bar{X}m_i$**	**$(X_i - \bar{X}m_i)^2$**
1	8	5	9.76	22.66
2	9	7	10.98	15.84
3	4	8	4.88	9.73
4	5	9	6.10	8.41
5	6	10	7.32	7.18
			Total	63.82

where $\bar{X}$ came from step 1.

Step 4 - Calculate $\hat{V}(\bar{X})$ = estimated variance for $\bar{X}$

$$\hat{V}(\bar{X}) = \left(\frac{N - n}{(N)(n)(m)^2}\right)\left(\frac{\Sigma(X_i - \bar{X}m_i)^2}{n - 1}\right)$$

$$= \left(\frac{30 - 5}{(30)(5)(6.4)^2}\right)\left(\frac{63.82}{4}\right)$$

$$= (0.004)(15.955) = 0.0649$$

Step 5 - Calculate the bound on the error of estimation

$$B = 1.96\sqrt{\hat{V}(\bar{X})} = 1.96\sqrt{0.064} = 0.4994$$

Step 6 - Calculate the 95 percent confidence interval for the population mean number of cavities per snag tree:

Lower limit: $1.22 - 0.4994 = 0.7206$

Upper limit: $1.22 + 0.4994 = 1.7194$.

Example 7—Assuming that information for example 6 is preliminary, how can we determine the number of clusters to sample if we want the bound on the error of estimation (B) to be within 0.1?

Step 1 - Calculate s_c^2 = estimate of the population variance among clusters

$$s_c^2 = \frac{\Sigma(X_i - \bar{X}m_i)^2}{n - 1}$$

$$= \frac{63.82}{4} = 15.955$$

Step 2 - Calculate

$$D = \frac{B^2\bar{m}^2}{Z^2} = \frac{(0.1)^2(6.4)^2}{(1.96)^2} = 0.1066$$

where:

1.96 is the Z value from the normal distribution for 95 percent confidence.

Step 3 - Calculate n' = total number of clusters to sample

$$n' = \frac{(N)(s_c^2)}{ND + s_c^2} = \frac{(30)(15.955)}{(30)(0.1066) + 15.955}$$

$$= \frac{(30)(15.955)}{19.153} = 24.99 \text{ or 25 clusters rounded up}$$

Two-Stage Sampling

Suppose we have clusters with so many elements in them that it is prohibitive to measure all elements in the cluster. It is natural to think of sampling elements within each cluster—that is, to measure only part of the elements within each cluster. This situation is a common one and is referred to as two-stage sampling.

Another common use of two-stage sampling is when it is apparent that even though there are many elements within a cluster, all elements are so nearly the same that to sample all of them would provide little additional information. The reasonable thing to do might be to measure only a part of the elements available within the cluster.

Two-stage sampling introduces a high degree of flexibility in defining clusters and sampling within them. The give and take between the number of clusters and the number of elements to be sampled within each cluster has been studied in some detail. Unfortunately, the results are complicated and beyond the scope of this publication. Interested readers are referred to one of the more extensive books on sampling (Cochran 1963; Kish 1965).

The following examples serve to give the reader a brief introduction to the concepts of two-stage sampling.

Example 8—Suppose that there are $N = 90$ clusters in a riparian zone and we can sample 10 clusters ($n = 10$) and 20 percent of the pools in each cluster. Estimate the mean depth of pools in the population, the bounds on the error of estimation (B), and the 95 percent confidence interval for the population mean (μ). Assume that there is a total of M = 4,500 pools in the 90 clusters. Data for each cluster have been used to calculate the cluster means ($\bar{X}_i$) and variances (s_i^2).

Step 1 - Tabulate data as follows:

Cluster	**Total pools** (M_i)	**Pools sampled** (m_i)	**Mean depth** $\bar{X}_i$	$(M_i)(\bar{X}_i)$	$(M_i\bar{X}_i - \bar{M}\bar{X})^{2}$*
1	50	10	5.40	270.00	900.00
2	65	13	4.00	260.00	400.00
3	45	9	5.67	255.15	229.52
4	48	10	4.80	230.40	92.16
5	52	10	4.30	223.60	268.96
6	58	12	3.83	222.14	318.98
7	42	8	5.00	210.00	900.00
8	66	13	3.85	254.10	198.81
9	40	8	4.88	195.20	2,007.04
10	56	11	5.00	280.00	1,600.00
	ΣM_i = 522			$\Sigma(M_i\bar{X}_i)$ = 2,400.59	$\Sigma(M_i\bar{X}_i - \bar{M}\bar{X})^2$ = 6,915.47

*Calculated $\bar{M}$ and $\bar{X}$ from Step 2 and Step 3 below

Cluster	s_i^2	$M_i(M_i - m_i) = A_i$	$s_i^2/m_i = B_i$	$(A_i)(B_i)$
1	11.38	2,000	1.138	2,276.00
2	10.67	3,380	0.821	2,774.98
3	16.75	1,620	1.861	3,014.82
4	13.29	1,824	1.329	2,424.10
5	11.12	2,184	1.112	2,428.61
6	14.88	2,668	1.240	3,308.32
7	5.14	1,428	0.643	918.20
8	4.31	3,498	0.332	1,161.34
9	6.13	1,280	0.766	980.48
10	11.80	2,520	1.073	2,703.96

$$\Sigma M_i(M_i - m_i)\frac{s_i^2}{m_i} = 21{,}990.81$$

Step 2 - Calculate $\bar{M}$ = average number of elements (pools) in each cluster

$$\bar{M} = \frac{M}{N} = \frac{4{,}500}{90} = 50 \text{ pools}$$

Step 3 - Calculate $\bar{X}$ = the estimated population mean depth for pools

$$\bar{X} = \frac{N}{(M)(n)} \Sigma M_i \bar{X}_i$$

$$= \frac{90}{(4{,}500)(10)} (2{,}400.59) = 4.8012 \text{ ft deep}$$

Step 4 - Calculate the estimated variance for $\bar{X}$

A. Calculate:

$$s_b^2 = \frac{1}{n-1} \Sigma(M_i\bar{X}_i - \bar{M}\bar{X})^2 = \frac{1}{10-1}(6{,}915.47)$$

$$= \frac{6{,}915.47}{9} = 768.4;$$

B. and calculate:

$$\hat{V}(\bar{X}) = \left[\left(\frac{N-n}{N}\right)\left(\frac{1}{n\bar{M}^2}\right)(s_b^2)\right] + \left(\frac{1}{nN\bar{M}^2}\right)\left[\Sigma M_i\,(M_i - m_i)\left(\frac{s_i^2}{m_i}\right)\right]$$

$$= \left[\left(\frac{90-10}{90}\right)\left(\frac{1}{(10)(50)^2}\right)(768.4)\right] + \left[\frac{1}{(10)(90)(50)^2}\right](21{,}990.81)$$

$$= 0.037095$$

Step 5 - Calculate bounds on the error of estimation

$$B = 1.96\sqrt{\hat{V}(\bar{X})} = 1.96\sqrt{0.037095} = 0.3775$$

Step 6 - Calculate the 95 percent confidence interval for the population mean pool depth (μ), which is:

Lower limit: $\bar{X} - B = 4.8012 - 0.3775 = 4.42$

Upper limit: $\bar{X} + B = 4.8012 + 0.3775 = 5.18$

Example 9—If M is unknown in example 8, calculate the estimate of the population mean depth of pools, the bounds on the error of estimation (B), and the 95 percent confidence interval for the population mean depth of pools.

Step 1 - Estimate μ = ratio estimate of the population mean μ

$$\bar{X}_r = \frac{\Sigma M_i \bar{X}_i}{\Sigma M_i} = \frac{2{,}400.59}{522} = 4.599 \text{ ft}$$

Step 2 - Complete tabulations for extension of table for example 8

$M_i^2 \bar{X}_i$	$(M_i \bar{X}_i)^2$	M_i^2
13,500.00	72,900.00	2,500
16,900.00	67,600.00	4,225
11,481.75	65,101.52	2,025
11,059.20	53,084.16	2,304
11,627.20	49,996.96	2,704
12,884.12	49,346.18	3,364
8,820.00	44,100.00	1,764
16,770.60	64,566.81	4,356
7,808.00	38,103.04	1,600
15,680.00	78,400.00	3,136
$\Sigma M_i^2 \bar{X}_i$ = 126,530.87	$\Sigma (M_i \bar{X}_i)^2$ = 583,198.67	ΣM_i^2 = 27,978

Step 3 - Calculate $\bar{M}$ = estimate of average number of pools per cluster

$$\bar{M} = \frac{\Sigma M_i}{n} = \frac{522}{10} = 52.2 \text{ pools per cluster}$$

Step 4 - Calculate estimated variance for μ

A. Calculate s_r^2:

$$s_r^2 = \frac{1}{n-1} \Sigma M_i^2 (X_i - \bar{X}_r)^2$$

$$= \frac{1}{n-1} \left[\Sigma (M_i \bar{X}_i)^2 - 2\bar{X}_r \, \Sigma M_i^2 \bar{X}_i + (\bar{X}_r)^2 \, \Sigma M_i^2 \right]$$

$$= \frac{583{,}198.67 - 2(4.599)(126{,}530.87) + (4.599)^2\,(27{,}978)}{9}$$

$$= \frac{583{,}198.67 - 1{,}163{,}830.94 + 591{,}757.11}{9}$$

$$= \frac{11{,}124.84}{9} = 1{,}236.09;$$

B. and calculate $\hat{V}(\bar{X}_r)$, the estimated variance of $\bar{X}_r$

$$\hat{V}(\hat{\mu}) = \left(\frac{N-n}{N}\right)\left(\frac{1}{n\bar{M}^2}\right)(s_r^2) + \left(\frac{1}{nN\bar{M}^2}\right) \Sigma M_i\,(M_i - m_i)\left(\frac{s_i^2}{m_i}\right)$$

$$= \left(\frac{90-10}{90}\right)\left(\frac{1}{(10)(52.2)^2}\right)(1{,}236.09) + \left(\frac{1}{(10)(90)(52.2)^2}\right)(21{,}990.81)$$

$$= \left(\frac{80}{90}\right)\left(\frac{1}{(10)(2{,}724.84)}\right)(1{,}236.09) + \left(\frac{1}{(10)(90)(52.2)^2}\right)(21{,}990.81)$$

$$= \left(\frac{80}{2{,}452{,}356}\right)(1{,}236.09) + \left(\frac{1}{2{,}452{,}356}\right)(21{,}990.81)$$

$$= 0.0403 + 0.0090 = 0.0493$$

Step 5 - Calculate bounds on error of estimation

$$B = 1.96\sqrt{\hat{V}(\hat{\mu})} = 1.96\sqrt{0.0493} = 0.435$$

Step 6 - Calculate the 95 percent confidence interval for the population mean (μ) for pool depth, which is:

Lower limit: $4.599 - 0.435 = 4.164$

Upper limit: $4.599 + 0.435 = 5.034$

Monitoring

The purpose of monitoring is to obtain information for use in evaluating responses of land management practices. Specific steps (fig. 2) must be followed if meaningful results are to be obtained from a monitoring study. Step 1 is the documentation of baseline condition, management potential, and problems attributed to the mix of land use practices adversely affecting a riparian area. Management potential is the level of riparian habitat quality that could be achieved through application of improved management. Potential will vary between sites because of several variables, including rainfall patterns, landform, and history of use. If potential is evaluated to be higher than the response capability of a site, and an objective is made to achieve better conditions than are possible, a management failure will obviously occur. This emphasizes the importance of developing objectives that are compatible with site potential.

Documentation of problems from all land use practices that affect a site requires a thorough analysis. For example, if the objective is to improve habitat to increase numbers of trout, it is possible that complex problems (fig. 3) must be solved or controlled before trout will benefit.

Before completing the objectives for riparian habitat management (step 2, fig. 2), holistic planning by an interdisciplinary group will be necessary because most sites will be subjected to multiple-use management. Therefore, riparian habitat objectives will have to be compatible with those of the overall multiple-use plan. If dominant-use management is to be applied to solely benefit a riparian area, it is advisable to involve individuals in other disciplines to assess potential for response to management. Depending on site-specific problems, the disciplines could include hydrology, plant ecology, and perhaps engineering if structural physical changes (such as rechannelization or installation of stream improvement devices) are considered. When objectives are specified, they must be stated in quantifiable and measurable terms; this is of paramount importance. An example of an objective could be to increase the density of shrubs from 25 to 50 percent. This specifically requires that existing conditions be documented for comparison with future management results.

The design of site-specific management plans for achieving riparian area objectives (step 3, fig. 2) requires multiple-use planning and conflict resolution. For example, suppose that timber harvesting, recreation, and mining are contributing to a degraded riparian habitat. It will be difficult, if not impossible, to design a management plan strictly for application in the area to solve problems caused by outside influences. Key considerations (Armour and others 1983) for a properly designed monitoring program (step 4, fig. 2) include the following:

1. Measurement of response to management is possible to determine through hypothesis testing if objectives are met. This prerequisite depends upon a clearly stated hypothesis (for example, H_0: shrub density increased 100 percent vs. H_a: shrub density increased <100 percent) that tracks with a management objective, and the variable must be responsive to management that will be applied. Additionally, measurement of the response with appropriate accuracy and precision must be feasible. Designation of variables that are difficult to measure and ones for which good measurement techniques have not been perfected should be avoided.

2. Control areas that will not receive management treatments must be included in the study. One precaution that must be taken in selecting control and treatment sites is that they must have the same premanagement characteristics and the same potential for response to management. This precaution is necessary if changes attributable to management are to be detectable. For example, if the objective is to improve overhanging streamside cover by 50 percent in a meadow, a control must be established in a similar meadow, not in an area with different landform features and response capabilities. The recommended approach for selecting control and treatment sites for comparison is to make the selections randomly in areas with similar premanagement conditions.

3. Resources must be available for monitoring through an adequate period to permit management responses to occur. This requirement is frequently neglected. If it is uncertain whether a monitoring program can be completed with adherence to the plan, the program should not be initiated.

4. Management must be consistent with the original plan throughout the study. Noncompliance with this condition is one of the most common problems thwarting studies. The problem occurs when changes are made in management, preventing accurate interpretations of data. An example of the problem could be when the establishment of easier access by fishermen to study sites in a stream has resulted in depletion of fish in treatment and control sites, masking influences of improved habitat conditions. Another example that happens frequently is the trespass of livestock and subsequent overgrazing and habitat change in control sites.

5. Confounding factors that can adversely affect the study must be controlled. These factors are defined as unplanned events or influences that adversely affect results of a study. Factors in this category include institutional influences (such as when an agency changes emphasis away from monitoring and a study is stopped), political pressures (such as when a user group uses influence to stop a study because potential results are disliked), equipment failure problems, changes in personnel conducting the study and inability to find suitable replacements, and biological effects (such as when natural variation is excessive in time and space, and responses to management are masked). Although it is impossible to guarantee that confounding problems will not occur, individuals involved with monitoring should consider them in advance to eliminate as many as possible.

6. Statistical tests to analyze information are designated when the monitoring program is designed and assumptions for proper use of the tests are met. Unfortunately, there has been a tendency for the advance consideration of statistical tests to be neglected, resulting in the collection of data and the expectation that a statistician "can make something out of it" after completion of field work. When this happens, the result is usually a disappointing conclusion that the study was useless. To prevent problems, individuals involved with designing monitoring programs should always obtain assistance from a statistician during the design phase. This will help avoid serious problems that cannot be corrected. Essentially the pilot study (step 5, fig. 2) for a monitoring project is conducted for the same reasons discussed for step 3, fig. 1. To help ensure that meaningful statistical tests are feasible,

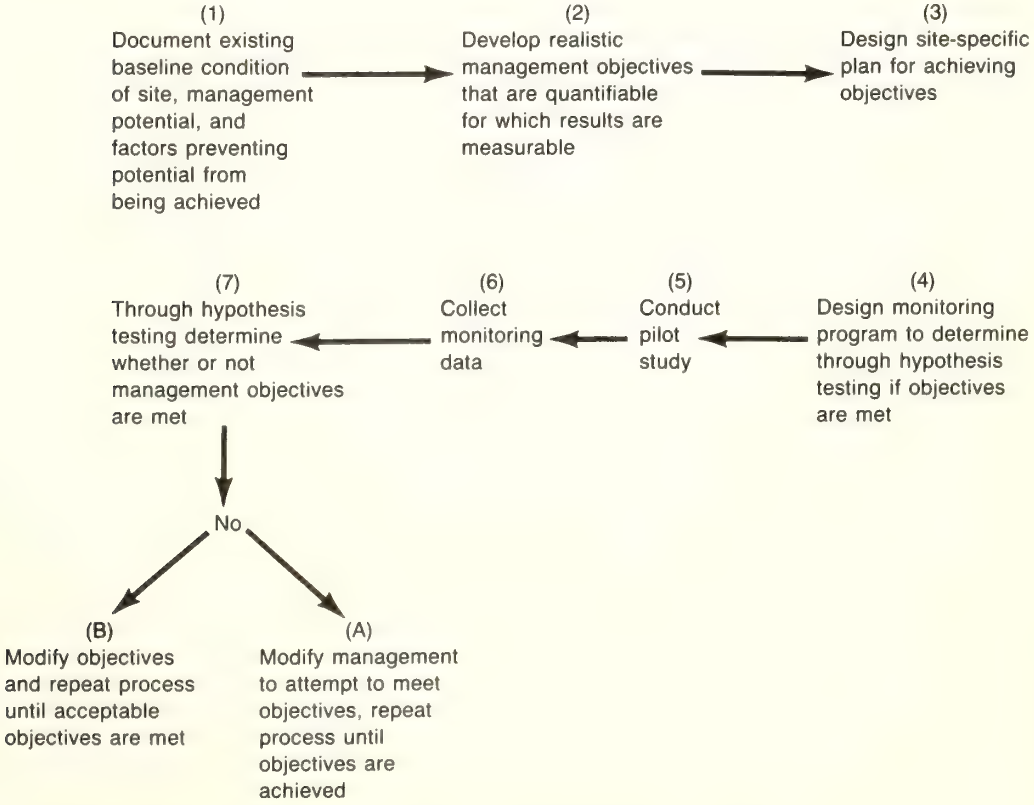

(1)
Document existing baseline condition of site, management potential, and factors preventing potential from being achieved
(2)
Develop realistic management objectives that are quantifiable for which results are measurable
(3)
Design site-specific plan for achieving objectives
(4)
Design monitoring program to determine through hypothesis testing if objectives are met
(5)
Conduct pilot study
(6)
Collect monitoring data
(7)
Through hypothesis testing determine whether or not management objectives are met
No
(B)
Modify objectives and repeat process until acceptable objectives are met
(A)
Modify management to attempt to meet objectives, repeat process until objectives are achieved

Figure 2—Steps for a monitoring program (modified from Armour and others 1983).

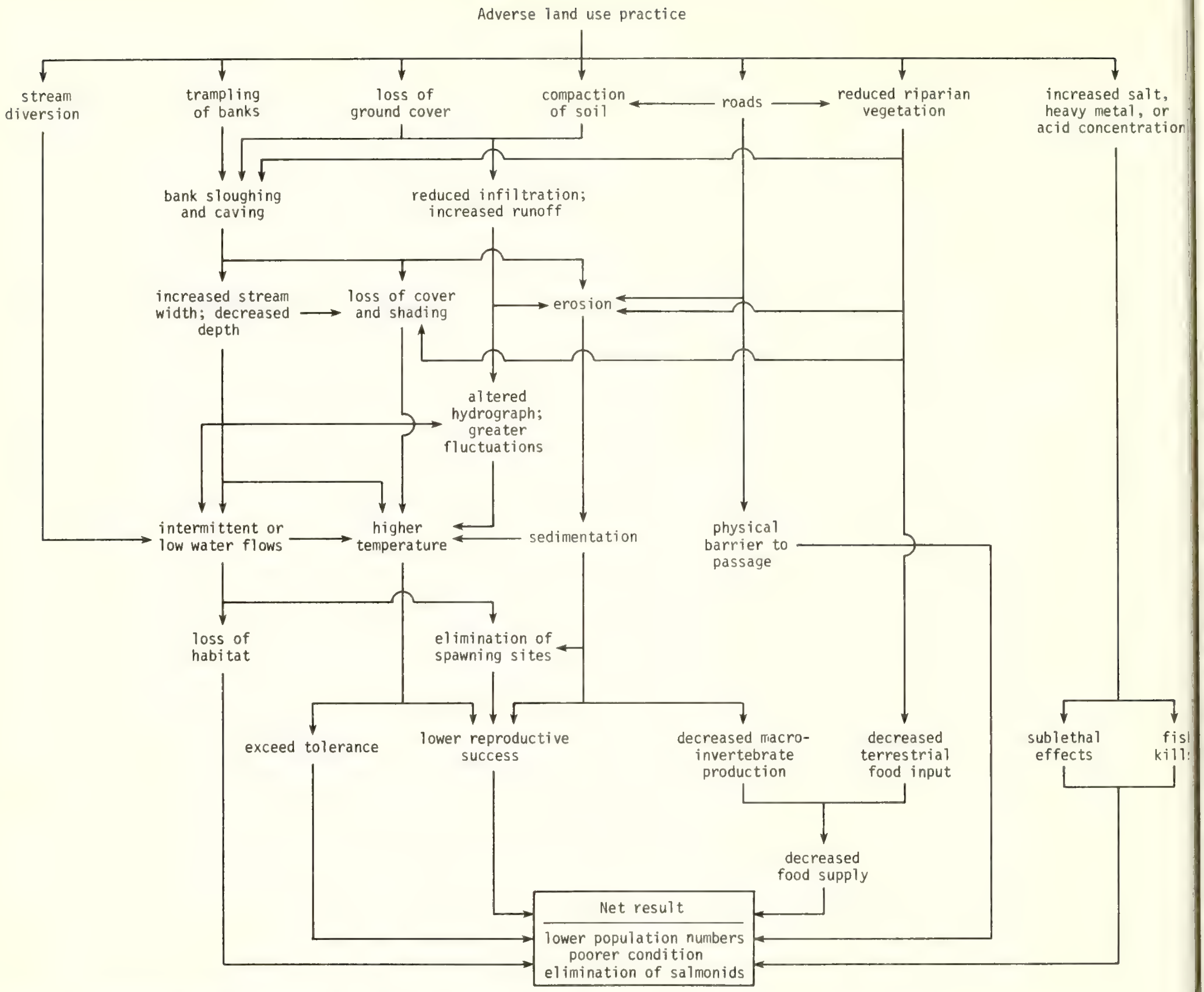

Adverse land use practice
stream diversion
trampling of banks
loss of ground cover
compaction of soil
roads
reduced riparian vegetation
increased salt, heavy metal, or acid concentration
bank sloughing and caving
reduced infiltration; increased runoff
increased stream width; decreased depth
loss of cover and shading
erosion
altered hydrograph; greater fluctuations
intermittent or low water flows
higher temperature
sedimentation
physical barrier to passage
loss of habitat
elimination of spawning sites
exceed tolerance
lower reproductive success
decreased macro-invertebrate production
decreased terrestrial food input
sublethal effects
fis
kill
decreased food supply
Net result
lower population numbers
poorer condition
elimination of salmonids

Figure 3—Some cause, effect, and impact relationships of adverse land use practices on salmonids (from Armour and others 1983).

assistance should be obtained from a statistician for this phase to refine approaches for the study. Once the pilot study is completed, assuming that appropriate premanagement data for control and treatment sites have been collected, management can be applied and monitoring (step 6, fig. 2) can proceed with strict adherence to the design specifications. If appropriate premanagement data have not been collected, this requirement must be fulfilled before management is applied. Failure to obtain data from preconditions and postconditions will preclude evaluation if management resulted in the achievement of stipulated objectives. Special considerations for step 6 must include: (1) maintenance of accuracy and precision in collecting data, (2) the expending of equal levels of effort and adherence to the same technical standards in control and treatment sites to prevent bias from influencing results of the study, and (3) the recording and processing of data suitable for retrieval and use in statistical analyses.

Statistical tests are used in step 7 to evaluate with a predetermined level of statistical confidence whether objectives were met. This level might not have to be as high (say, 95 or 99 percent) as would be expected for research, but the price for a lower level is an increased chance for a type I error (claiming a difference when it does not exist). When tests are performed, the determined confidence level must not be arbitrarily altered (say, from 95 to 85 percent) if results do not conform with preconceived perceptions.

Common errors to avoid when using statistical tests include inaccurate data entry, errors in rounding numbers, use of incorrect degrees of freedom, and incorrectly reading statistical tables (such as tables of t and F values).

Based on results of hypothesis testing, it is possible to conclude with a stipulated level of statistical confidence whether objectives are met. If they are not met, there are two options: modify objectives and repeat the process in figure 2 until they are eventually met, or modify management and repeat the process until success is achieved.

One concept that must be emphasized is that monitoring should not result in a strict "pass" or "fail" conclusion. There cannot be a failure if, in the future, negative results contribute to avoidance of management practices that do not work. Therefore, it is equally important to document unsuitable practices to avoid if the art of riparian resource management is to progress.

MEASURING VEGETATION

Vegetation in the riparian ecosystem includes vegetation on a streambank and on a flood plain that has some control over streamside conditions. Riparian vegetation helps to stabilize the streambanks, control nutrient cycling, reduce water velocity, provide cover and food for fish, and intercept and store energy from solar radiation. Riparian vegetation controlling the sunlight reaching the stream limits the energy base for photosynthesis.

Vegetative Use by Animals

We have successfully evaluated this variable on streambanks using channel cross sections (transects) placed perpendicular to streamflow (Platts and others 1983). Vegetative use under a transect line and within 5 ft of the shoreline or to the top of the streambank, whichever is larger, can be rated visually. This use evaluation includes vegetation disturbed (grazed and trampled) during the present growing season, and potential plant growth that does not exist because of past disturbance of vegetation. An example of loss because of use would be in areas where vegetation no longer exists because the streambank was dredged or trampled, or where vegetation was eliminated on a major cattle crossing. The rating, however, applies mainly to recent vegetative use. If use is determined on only one occasion or only once a year, it should be done as soon as possible after harvesting ceases and before plant regrowth can occur.

The vegetative use rating (this mainly applies to herbaceous vegetation) is stratified into four classes:

Rating (percent)	**Description**
0 to 25—light	Vegetative use is light or nonexistent. Almost all the potential plant biomass at present stage of development remains. The vegetative cover is close to that which would occur naturally without use. If bare areas exist (such as bedrock) they are not a result of loss of vegetation from land uses.
26 to 50—moderate	Vegetative use is moderate and at least half of the potential plant biomass remains. Average plant stubble height is greater than half of its potential height at its present stage of development. Plant biomass no longer on site because of past grazing is considered as vegetation that has been used.
51 to 75—high	Vegetative use is high and less than half of the potential plant biomass remains. Plant stubble height is usually over 2 inches (on many ranges). Plant biomass no longer on site because of past grazing is considered as vegetation that has been used.
76 to 100—extreme	Use of the streamside vegetation is high and only short stubble remains (usually less than 2 inches on many ranges). Almost all the potential vegetative biomass has been used. Only the root system and part of the stem remain. The potential plant biomass that no longer exists because of use is considered as vegetation that has been used.

Once the observer has decided the class (light to extreme), then the actual percentage of use is determined. For example, if the vegetation (grasses and forbs) has been reduced to less than a quarter of potential (usually 2 inches stubble standing height on many ranges), the class rating is between 76 and 100 percent. If the vegetation is removed to almost ground level, the final intraclass rating would be 100 percent. If the vegetation is slightly less than a quarter (usually less than 2 inches stubble height) of its potential and there are no areas without vegetation from vegetative use, then the intraclass rating would be about 76 percent.

Table 2—Comparison of streamside herbage use using the visual method versus the electronic herbage meter

	1979			1980		
Study area	**Meter**	**Visual**	**Δ%**	**Meter**	**Visual**	**Δ%**
Idaho (10 streams)	45	44	1	58	60	2
Nevada (2 streams)	81	68	13	63	57	6
Utah (1 stream)	84	76	8	104	87	17

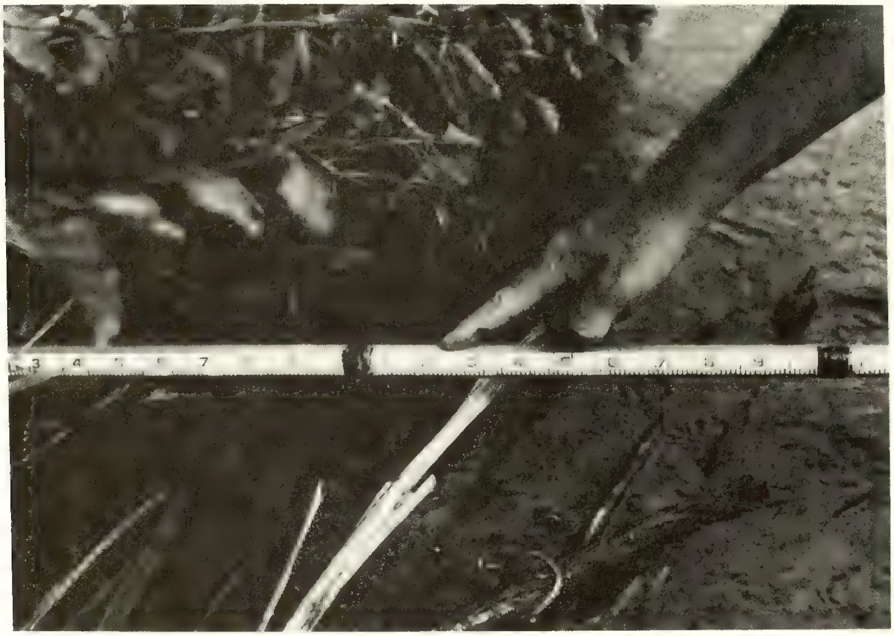


Figure 4—Measuring overhanging streamside vegetation.

In our studies, the 95 percent confidence intervals about the means (±12 percent) are high but still within acceptable limits for most streams studied (appendix 2). Precision and accuracy are good. The observer should be well trained and have ungrazed plots (utilization cages) for constant comparison. Our visual estimates of vegetative use were on average quite close to use estimates obtained with actual measurements using the electronic capacitance herbage meter (table 2).

Vegetative Overhang

Vegetative overhang indirectly provides fish food, directly provides cover, and shades the water from solar radiation (fig. 4). Overhang is a valuable variable to use when evaluating land use effects, such as livestock grazing, logging, and road construction, that have altered or could alter the riparian habitat. Vegetative overhang rates only that vegetation overhanging the water column. This is a direct measurement to the nearest 0.1 ft of the vegetation (excluding tree trunks or downed logs) within 12 inches (vertical) of the water surface and overhanging the water column (fig. 5). That part of the canopy higher than 12 inches enters the evaluation through the canopy closure and density and solar integrator methods. The vegetative overhang is measured along a transect line, beginning at the farthest protrusion of the streambank over the water surface, to the farthest point that vegetation covers the water column. This measurement does not include the undercut. Therefore, bank undercut and vegetative overhang combined give the total immediate overhead cover, excluding other types of cover (such as water surface turbulence).

In our studies the 95 percent confidence intervals around the overhang means (±15.7 percent) are fairly wide, but year-to-year precision and accuracy rate fair (appendix 2).

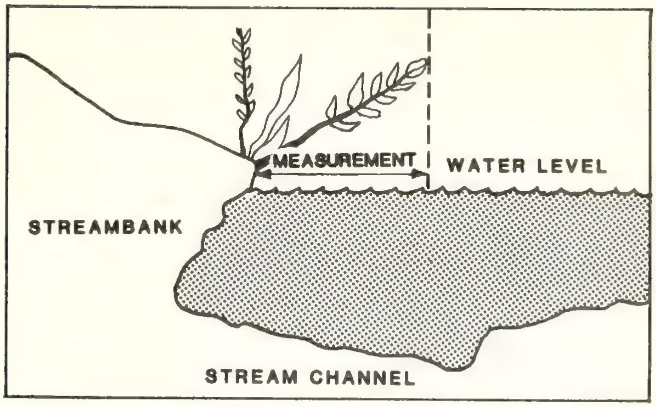


Figure 5—Measurement of overhanging vegetation.

Table 3—Streambank stability rating

Rating		Description
Units	*Percent*	
4	75-100	Over 75 percent of the streambank surface is covered by vegetation in vigorous condition or by boulders and rubble. If the streambank is not covered by vegetation, it is protected by materials that do not allow bank erosion.
3	50-74	Between 50 and 74 percent of the streambank surface is covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are protected by materials that allow only minor erosion.
2	25-49	Between 25 and 49 percent of the streambank surface is covered by vegetation or by gravel or larger material. The area not covered by vegetation is covered by materials that give limited protection.
1	0-24	Less than 25 percent of the streambank surface is covered by vegetation or by gravel or larger material. That area not covered by vegetation provides little or no control over erosion and the banks are usually eroded each year by high water flows.

Streambank Stability

The ability of vegetation and other materials on the streambank to resist soil and vegetative erosion from flowing water and ice is rated in table 3. This rating relates primarily to stability generated by vegetative cover, except in those cases where bedrock, boulder, or rubble stabilizes the streambanks. The rating takes all these sources of protective cover into account and is rated in four classes. Once the class has been determined, the observer decides the actual percentage. The rated portion of the bank or flood plain includes only that area intercepted by the transect line within 5 ft of the stream or to the top of the bank, whichever is the larger. Surprisingly, the confidence intervals around the means (units) from our study sites are quite low (about ±3 percent). However, year-to-year precision and accuracy rated only fair (appendix 2). Therefore, the user should be cautious in its use.

Streamside Cover

This rating only provides gross evaluation. The measurement is used to evaluate major vegetative type conversions or for information for aquatic classification. For more refined evaluation, the riparian habitat community typing described later has more potential value.

The cover rating considers all material (organic and inorganic) on or above the streambank that offers stream shading and protection from soil erosion and provides escape cover or resting security for fish.

Rating	Description
5	Shrubs are the dominant streamside vegetation.
4	Tree forms are the dominant streamside vegetation.
3	Grass forms are the dominant streamside vegetation.
2	Forbs are the dominant streamside vegetation.
1	Over 50 percent of the streambank transect line intercept has no vegetation and the dominant bank material is made up of such materials as soil, rock, bridge materials, road materials, culverts, and mine tailings.

The only area of streambank rated is that intercepted by the transect line that covers the exposed streambottom, bank, and top of bank.

Initially in determining this rating, all vegetation along the stream that would reach the stream (if it were laid down toward the stream) was used in the analysis. This procedure caused high observer variation and increased confidence intervals. Therefore, we revised it to include only that cover intercepted by the transect line. This decreased the observer error and confidence intervals. The higher level offsite vegetation, not considered in this rating, is accounted for by the canopy closure, density, and solar integrator and shade methods.

The cover rating is effective in evaluating the effects of such activities as channelization, logging, or cattle grazing on riparian habitat. This measurement in our studies had low confidence intervals about the mean (±4.1 percent) mainly because dominant cover tends to be uniform and observers evaluate the same conditions alike even though they may not rate it correctly. Year-to-year precision and accuracy were poor and demonstrate that special emphasis must be placed on attaining accuracy when using this measurement.

Electronic Forage Analysis

Because grazed rangelands frequently cover large areas of land surface, determination of forage production and use by grazing animals must be based on estimation. Estimates are presently obtained through a variety of techniques that not only vary between land management agencies but can also vary between individuals within the same agency. For example, the USDA Forest Service Range Environmental Analysis Handbook, Rocky Mountain Region (1973) describes three methods for estimating forage production based on total plant production, whereas the USDA Soil Conservation Service National Range Handbook (1979) describes five techniques that may be used in combination for estimating livestock use of key forage species in key areas. This inconsistency leads to difficulties in comparing range management information and can cause breakdown in effective communication between research and management personnel.

Such problems become even more acute in evaluating the effects of range management practices on riparian ecosystems. The National Range Handbook even states that "small areas of natural concentration [of livestock], such as those adjacent to water, salt, or shade, are not key grazing areas"; therefore, riparian areas may unconsciously not receive adequate attention in range analyses. On the other hand, the USDA Forest Service Range Analysis Handbook, Intermountain Region (USDA Forest Service 1983), provides clear-cut guidelines for determining the extent of riparian ecosystems and mentions the need for interaction between grazing needs and those of other resource uses, such as fisheries. Those involved in research and management of fisheries resources in the area of overlap between range and fisheries ecology are confronted with some difficulty in determining and applying forage evaluation techniques and relating them back to fishery concerns in diverse geographical settings. Consequently, much needs to be done to standardize herbage evaluation procedures and to promote communication between interacting agencies.

One way to bridge this gap is by adapting the use of electronic capacitance herbage meters to riparian-fishery habitat evaluations. These meters provide for rapid, accurate estimation of standing herbage biomass (phytomass) with low costs in human labor and allow nondestructive analysis of the vegetation sampled. Because capacitance is directly related to vegetative weight, it is a simple matter to estimate phytomass over relatively large areas by double sampling (Cochran 1963). The use of the herbage meter represents a substantial step forward in the standardization of objective and integrated range and riparian-fishery habitat evaluation techniques.

Instrument Design and Limitations—The principle behind electronic capacitance metering of vegetation (Neal and Neal 1973) is based on the high dielectric constant of moisture contained in the vegetation relative to the low dielectric constant of the meter's sensing unit. Two parallel oscillators are initially set to the same frequency relative to a no-yield (zero vegetative weight) reference. When vegetation is subsequently introduced to the meter's sensing field, one oscillator is shifted in frequency by an amount proportional to the weight of the vegetation. The meter displays this frequency shift as a dimensionless number that is used to determine corresponding vegetative weights through regression analysis. It is therefore necessary to keep extraneous electrical conductors (such as basalt rocks or metal stakes) away from the meter when measurements are being taken.

The Neal Electronics models 18-2000 and 18-3000 are similar but slightly different in use. The 18-2000 must be "tuned" with respect to its coarse frequency oscillation each season, and zeroed to no-yield (vegetation absent) by mechanical fine frequency adjustment before each use and at least once during use. The 18-3000 needs only to be switched into "calibration" mode and a reading taken in a no-yield situation to set its oscillators. Both should be reset to zero during sampling if the ambient temperature changes by 10 °F or more. Readings are easily obtained by pushing the "read" button and stepping back to avoid influencing the measurement.

Each of the two meters is approximately 1 ft wide by 1.9 ft long by 2.1 ft high, and rectangular. And at a weight of 23 lb, neither is too heavy to be carried over even terrain for several hours. However, the size and shape of the meters do lead to some difficulties on the uneven terrain associated with riparian areas. Care must be taken to avoid damaging a machine by striking it against any solid objects. This requires periods of carrying it one-handed or overhead, considerably increasing the risk of stumbling and consequent injury to the worker. The wide, four-legged stance of each instrument also makes it prone to toppling over on uneven terrain, but this can be alleviated by holding it securely with a rope of nonconductive material attached to the instrument's carrying handle. Both models have proven to be reasonably durable under conditions normally encountered in riparian areas.

Capacitance measurements can be taken with the machine at any angle, but the user must remain clear of the sensing field during measurement. Vegetation that fits easily within the meter's probe array is most conveniently measured, but taller vegetation can be measured by folding upper projections into the probe array. Care should be taken to include only vegetation that is taller in this manner, and to not include vegetation that extends laterally out of the meter's field.

Field Methods—Streamside herbage data are quickly and easily collected, and little training of field personnel is required. To set up a study or monitoring program with the herbage meter, the first step is to select the sites to be compared. These may consist of sites for which standing phytomass in each are to be compared directly, paired sites in which one is ungrazed to determine potential production for comparison with a similar but grazed site for estimating harvest by livestock, a grazed site used in conjunction with ungrazed utilization cages in which potential production can be estimated, or a streambank pasture where increases in productivity resulting from rehabilitative plantings need to be monitored. Whatever the combination of study sites selected, two sets of data must be collected: a large primary data set, which is measured by the meter for capacitance only, and a smaller secondary data set that is both metered and clipped and weighed to determine the regression relationship of vegetative weights on capacitance readings. The secondary sample can be either a subsample of the primary data set, or an independent sample of vegetation like that of the primary set, depending on whether nondestructive sampling of the primary sample is required.

The size of the primary data set is left to the investigator. Back and others (1968) suggest that little is gained by exceeding 25 meter readings in a site, and that the advantages gained by this estimation technique fall off rapidly as more sample plots are included. The heterogeneity of riparian vegetation requires somewhat greater thoroughness in sampling to adequately determine the productivity of the study site. If plots are to be resampled at a later date (an advantage of the nondestructive technique), their location should be referenced to a permanent marker. Metal stakes can be used for this purpose if located far enough from the plot to avoid interfering with the meter's sensing field. Plastic stakes avoid this problem. If riparian or stream cross-section markers are used, the coordinates of permanent sample plots can be easily established by aligning the center line of the long axis of the meter along the transect line. The location can be permanently referenced by designating a distance away from the stake and the stream with a negative (−) sign and between the stake and the stream with a positive (+) sign (fig. 6). Capacitance of the plot is determined by taking the average of three readings, or by taking only two readings if the same meter reading occurs twice. No extraneous conductive material, especially the investigator's body, should be within 2 ft of the machine during measurement. Enough time elapses after pushing the "read" button before actual measuring begins for the investigator to step back.

The secondary data set can be a subsample of the primary set, or an independent set. In the former case, if selection of secondary plots is accomplished randomly or systematically, the vegetation sampled in the secondary sample will be representative of that in the primary sample. If the secondary data set is an independent sample, care must be taken to assure that it is representative of the vegetation in the primary samples (Reese and others 1980). One way to assure similarity is to ensure that the proportions of shrub and grass (or forb) are similar in each sample and that distances from water are similar; a software package described later is designed to simultaneously conduct these analyses when such

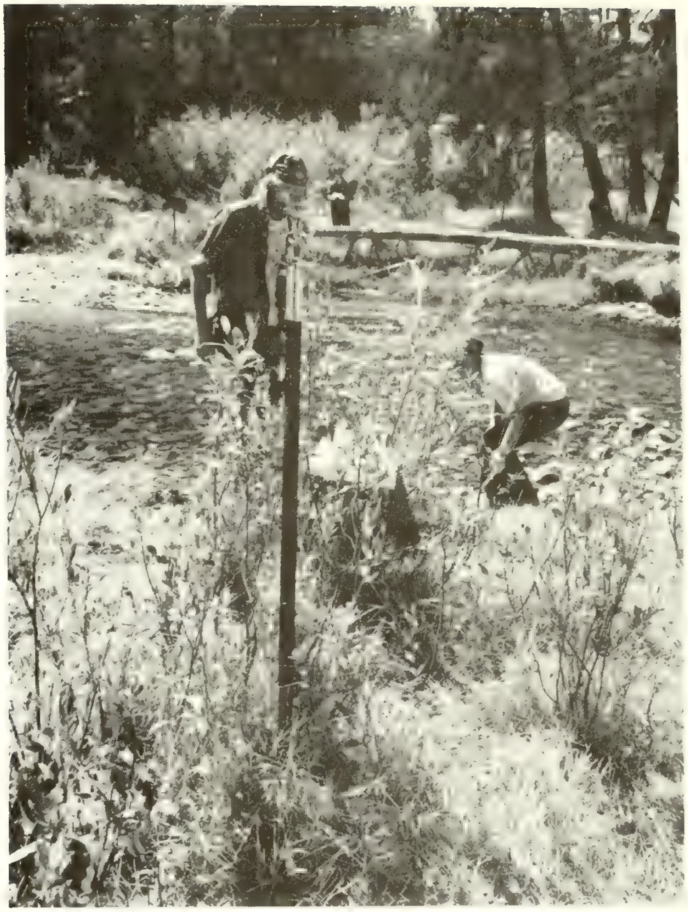


Figure 6—Coordinates of permanent sample plots can be established using cross-section markers.

field data are collected. Similarity cannot be accomplished by similarity of meter readings, because an artificially wide range of meter readings and weights should be obtained to establish an adequate regression relationship (Cochran 1963), and because capacitance for unlike vegetation may be similar but weights may vary. There should be at least one secondary sample plot for every five primary plots (Currie and others 1973; Neal and others 1976), though we recommend a ratio of 1:4 to help ensure development of an adequate regression relationship in the heterogeneous riparian area.

Vegetation within the sensing field of the meter is marked off by positioning a 1- by 2-ft frame around the sampled plot, being careful to remove tall vegetation that extends beyond the meter's field, clipped according to the three-dimensional technique of Currie and others (1973) and weighed in either grams or ounces. Because annual forage production is of principal concern, grasses and forbs within the frame are clipped on a plane (ignoring ground contour) to a 0.5-inch stubble height; litter should be ignored. For shrubby species, only new growth should be removed and included in the weighed sample, because dead wood in the sample plot has little capacitance and would only distort the regression relationship if weighed (Carpenter and others 1973). We have used chiefly fresh vegetative weights, determined concurrently with clipping, in our studies, but dry weights may also be used. Vegetative samples may be ovendried at 140-158 °F until stable weights are obtained (Chambers and Brown 1983).

Auxiliary Habitat Variables—Several auxiliary riparian habitat variables, which were briefly mentioned previously, are also routinely collected. These variables provide additional information about the character of the vegetation being sampled and allow instantaneous comparison of site-specific (primary) and calibration (secondary) samples. The variables also provide evaluations of trends within sites over time. The variables are measured concurrently with the taking of capacitance readings and include coverage, vegetative composition, and shortest distance to stream.

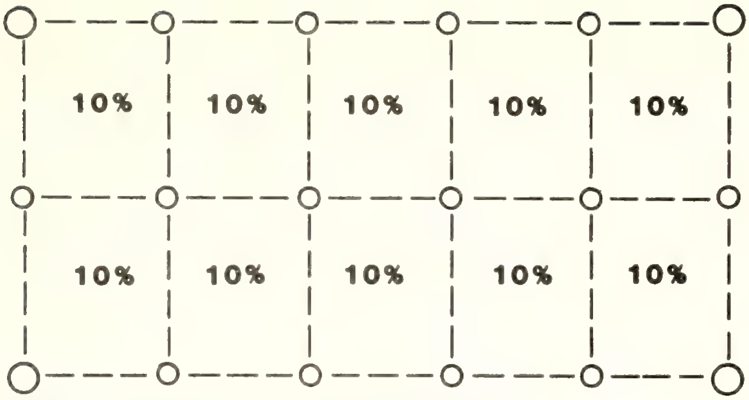


Figure 7—Herbage meter 10 percent surface area plots.

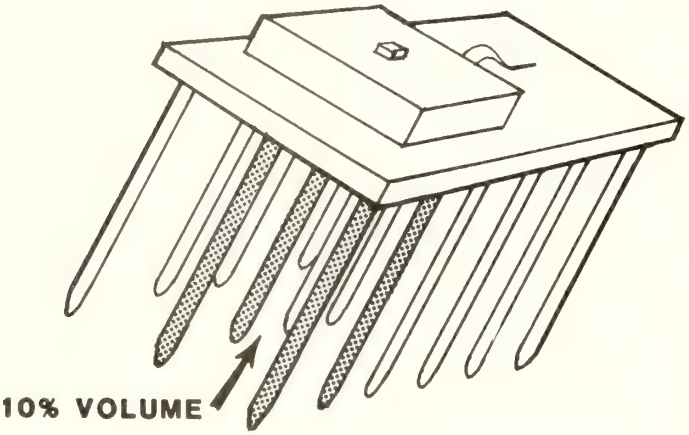


Figure 8—Example of rectangular volumes.

Cover—This is a measure of the actual proportion within an individual sample plot that is covered or not covered by actively growing vegetation. This is a surface area measurement and is visually estimated within the meter's probe array. The probes of the herbage meter form squares, each defining approximately 10 percent of the sample plot (fig. 7). Using these 10 microplots as guides, the percentage of covered and exposed ground within the sample plot can be estimated. When averaged over the entire sample, the percentages of covered and exposed ground within each study site can be estimated.

Species Composition—This measurement evaluates the relative amounts of shrubby and herbaceous species. By imagining individual rectangular volumes for each of the spaces defined by the probes (fig. 8), the volumetric proportion, which totals 100 percent, that each type of vegetation contributes to the biomass of the sample plot can be estimated. This procedure is analogous to separating each sample to life form and determining the contribution of each. It is a somewhat unconventional approach, but is suggested by the "harvest method" of production analysis suggested by Chambers and Brown (1983).

Distance to Stream—Unlike the other measurements described, this variable was not included to provide a precise description of the study plot. The shortest distance from the meter to permanent water derived from the stream is measured to the nearest 0.1 ft, usually from a center probe of one of the meter's faces. Occasionally, however, measuring from a center probe is unrealistic compared to measuring from a corner probe; in such cases, a corner probe may be used. While not intended to be a precisely measured factor, this variable does allow a gross evaluation of the average location of sample plots in each site and in the calibration sample with respect to the nearest stream-derived water. It will also allow some early indications of streambank erosion. A sample field data form of the type we use is shown in appendix 3.

Regression Analyses—Regression analyses with capacitance meters have traditionally been conducted using a linear regression model, and good results have been obtained on planted ranges (Currie and others 1973), native herbaceous vegetation (Neal and others 1976), native shrub ranges (Morris and others 1976), and riparian vegetation (Platts and Nelson 1983). Although linear regression analysis generally provides adequate biomass estimation, it has been suggested that logarithmic transformation of the explanatory variable (X) and response variable (Y) may provide increased precision in some situations (Terry and others 1981), though care in selecting the model of choice is necessary (Nelson and others in press). (These variables have been traditionally referred to as the independent and dependent variables, respectively; the more modern terminology is used here.)

The mathematics of these two models are similar, the former linear on arithmetic graph paper and the latter linear on double-logarithmic graph paper. A computer program has been developed to calculate the regression relationships and estimate both phytomass (yield) and differences in phytomass (yield differential), expressed as a percentage, between study pastures (see appendix 4). It was developed on a Hewlett-Packard 9845T microcomputer and allows data to be entered from a mass storage device (diskette or tape cartridge), performs all double sampling computations for biomass and use estimation from either a linear or logarithmic regression model, and runs basic statistical analyses on up to eight auxiliary habitat variables (see appendix 4). Deciding which model better describes the data is left to the judgment of the individual investigator.

Linear Regression—Linear regression conforms to the general model:

$$\mu = \alpha + \beta X + \varepsilon \tag{1}$$

estimated by the regression equation:

$$\hat{Y} = a + bX \tag{2}$$

where μ is the true mean vegetative weight at meter reading X, which is estimated by $\hat{Y}$, α and β are regression coefficients estimated by a and b respectively, and ε is random error in weights. The coefficient a is the Y-axis intercept, and b describes the average change in weight for a respective change in meter reading. $\hat{Y}$ can be used to estimate either individual vegetative weights for metered plots, or to estimate mean vegetative weights for study sites from mean meter readings. Use of the linear model assumes that vegetative weights are distributed normally with mean μ and variance σ^2 over the range of meter readings.

Initial calculations to fit the model proceed as follows:

$$n_1 = \text{secondary sample size} \tag{3}$$

$$\bar{X}_s = \frac{\sum_{i=1}^{n_1} X_{si}}{n-1}$$

$$= \text{average of the meter readings from the secondary sample} \tag{4}$$

$$\bar{Y}_s = \frac{\sum_{i=1}^{n_1} Y_{si}}{n=1}$$

$$= \text{average of the vegetative weights in the secondary sample} \tag{5}$$

$$\mathrm{SS}(X) = \sum_{i=1}^{n_1} (X_{si} - \bar{X}_s)^2 = \sum_{i=1}^{n_1} X_{si}^2 - \frac{(\sum_{i=1}^{n_1} X_{si})^2}{n_1}$$

$$= \text{sum of squares of deviations of meter readings} \tag{6}$$

$$\mathrm{SS}(Y) = \sum_{i=1}^{n_1} (Y_{si} - \bar{Y}_s)^2 = \sum_{i=1}^{n_1} Y_{si}^2 - \frac{(\sum_{i=1}^{n_1} Y_{si})^2}{n_1}$$

$$= \text{sum of squares of deviations of vegetative weights} \tag{7}$$

$$\mathrm{S}(XY) = \sum_{i=1}^{n_1} (X_{si} - \bar{X}_s)(Y_{si} - \bar{Y}_s)$$

$$= \sum_{i=1}^{n_1} (X_{si} Y_{si}) - \frac{[(\sum_{i=1}^{n_1} X_{si})(\sum_{i=1}^{n_1} Y_{si})]}{n_1}$$

$$= \text{sum of cross products} \qquad (8)$$

where the subscript s_i denotes the ith value from the secondary sample, X denotes meter readings, Y denotes vegetative weights, and $\sum_{i=1}^{n_1}$ indicates summation of i values of a variable over the range 1 to n_1.

The relevant regression coefficients and comparative statistics are then calculated as follows:

$$b = \mathrm{S}(XY)/\mathrm{SS}(X) = \text{regression coefficient} \qquad (9)$$

$$a = \bar{Y}_s - b\bar{X}_s = Y\text{-axis intercept or constant} \qquad (10)$$

$$\mathrm{SE}(YX) = \sqrt{\frac{[\mathrm{SS}(Y) - \mathrm{S}(XY)^2/\mathrm{SS}(X)]}{n_1 - 2}}$$

$$= \text{standard error of estimate} \qquad (11)$$

$$r^2 = \frac{[\mathrm{S}(XY)^2/\mathrm{SS}(X)]}{\mathrm{SS}(Y)}$$

$$= \text{coefficient of determination} \qquad (12)$$

$$C = \mathrm{S}(XY)/n_1 - 1 = \text{covariance}$$

$$\mathrm{SE}(\hat{Y}) = \mathrm{SD}(YX)\sqrt{(1/n_1) + \frac{(X - \bar{X}_s)^2}{\mathrm{SS}(X)}}$$

$$= \text{standard error of } \hat{Y} \qquad (13)$$

Confidence intervals can be determined for the estimated vegetation weight by:

$$\hat{Y} - t\,\mathrm{SE}(\hat{Y}) \leqslant \mu \leqslant \hat{Y} + t\,\mathrm{SE}(\hat{Y}) \qquad (14)$$

where μ is the true mean vegetative weight corresponding to the selected meter reading and t is Student's t for the desired probability level with $n_1 - 2$ degrees of freedom (see appendix 1).

For example, suppose we had a secondary data set with the values of meter readings (X_{si}) and vegetative weights (Y_{si}) as shown in table 4. Note that two zero values representing setting the machine to no yield must be included in the linear regression analysis. Then:

$$n = 7$$

$$\bar{X}_s = \frac{83}{7} = 11.9$$

$$\bar{Y}_s = \frac{176}{7} = 25.1$$

$$\mathrm{SS}(X_s) = 1{,}703 - \frac{(83)^2}{7} = 718.9$$

$$\mathrm{SS}(Y_s) = 8{,}614 - \frac{(176)^2}{7} = 4{,}188.9$$

$$\mathrm{S}(XY) = 3{,}759 - \frac{[(83)(176)]}{7} = 1{,}672.1$$

Table 4—Hypothetical secondary meter readings (X_{si}) and vegetative weights (Y_{si}) with corresponding squares, cross products, and sums

	Secondary data		Squares and cross products		
	X_{si}	Y_{si}	X^2_{si}	Y^2_{si}	$X_{si}Y_{si}$
	0	0	0	0	0
	0	0	0	0	0
	17	22	289	484	374
	28	70	784	4,900	1,960
	5	10	25	100	50
	11	23	121	529	253
	22	51	484	2,601	1,122
Totals ($\sum_{i=1}^{n}$)	83	176	1,703	8,614	3,759

and

$$b = \frac{1{,}672.1}{718.9} = 2.3$$

$$a = 25.1 - (2.3)(11.9) = -2.3$$

$$\hat{Y} = -2.3 + 2.3\,x$$

$$\mathrm{SE}(YX) = \sqrt{\frac{4{,}188.9 - [(1{,}672.1)^2/718.9]}{5}} = 7.7$$

$$r^2 = \frac{[(1{,}672.1)^2/718.9]}{4{,}188.9} = 0.93$$

$$C = 1{,}672.1/6 = 278.7$$

Consequently, for a hypothetical meter reading of 12:

$$\hat{Y} = 25.3$$

$$\mathrm{SE}(\hat{Y}) = (7.7)\sqrt{(1/7) + \frac{(0.1)^2}{718.9}} = 2.9$$

and 95 percent confidence interval:

$$25.3 - (2.571)(2.9) \leqslant \mu \leqslant 25.3 + (2.571)(2.9)$$

or 15.2 ± 7.5

with $n-2 = 5$ degrees of freedom. These confidence limits are rather wide but should be expected to decrease with larger sample sizes or with a reduction in SE(YX), or with both. This procedure applies only to estimates of weight from individual meter readings, which are assumed to be free of sampling error. Estimation from mean meter readings is addressed later.

Logarithmic Regression—Logarithmic regression is performed similarly following transformation of the variables. Logarithms to any base may be used, but we will restrict ourselves here to natural (base e) logarithms. It is important to eliminate the two zero points from this analysis because the logarithm of 0 does not exist and the curve automatically originates at the origin. Logarithmic regression conforms to the general model:

$$\ln\mu = \alpha_1 + \beta\ln X + \ln\varepsilon \qquad (15)$$

or the mathematically identical definition:

$$\mu = \alpha_2 X^{\beta\varepsilon} \qquad (16)$$

estimated by the regression equations:

$$\ln\hat{Y} = a_1 + b\ln X \qquad (17)$$

or

$$\hat{Y} = a_2 X^{b} \qquad (18)$$

respectively, where μ is true mean vegetative weight at meter reading X, which is estimated by $\hat{Y}$; α_1, α_2, and β are regression coefficients estimated by a_1, a_2, and b_1, respectively; $\alpha_1 = \ln\alpha_2$, $a_1 = \ln a_2$; and ε is random error in weights. $\hat{Y}$ can be used to estimate individual vegetative weights for a given meter reading, or it can estimate mean vegetative weight from mean meter readings; in the latter case, knowledge of ε is sacrificed. Use of this model assumes that data are distributed normally after transformation, with mean μ and variance σ^2 over the range of meter readings.

Initial calculations for fitting logarithmic regression involve transforming the secondary data values to natural logarithms and calculating as for the linear model:

n_2 = secondary sample size less the two zero values (19)

$$\overline{\ln X_s} = \frac{\sum_{i=1}^{n_2} \ln X_{si}}{n_2}$$

= average of the natural logarithms of the secondary meter readings (20)

$$\overline{\ln Y_s} = \frac{\sum_{i=1}^{n_2} \ln Y_{si}}{n_2}$$

= average of the natural logarithms of secondary vegetative weights (21)

$$\begin{aligned} \mathrm{SS}(\ln X) &= \sum_{i=1}^{n_2} (\ln X_{si} - \overline{\ln X_s})^2 \\ &= \sum_{i=1}^{n_2} \ln X_{si}^2 - \frac{(\sum_{i=1}^{n_2} \ln X_{si})^2}{n_2} \end{aligned}$$

= sum of squares of deviations of natural logarithms of meter readings (22)

$$\begin{aligned} \mathrm{SS}(\ln Y) &= \sum_{i=1}^{n_2} (\ln Y_{si} - \overline{\ln Y_s})^2 \\ &= \sum_{i=1}^{n_2} \ln Y_{si}^2 - \frac{(\sum_{i=1}^{n_2} Y_{si})^2}{n_2} \end{aligned}$$

= sum of squares of deviations of natural logarithms of vegetative weights (23)

$$\begin{aligned} \mathrm{S}(\ln X \ln Y) &= \sum_{i=1}^{n_2} (\ln X_{si} - \overline{\ln X_s})(\ln Y_{si} - \overline{\ln Y_s}) \\ &= \sum_{i=1}^{n_2} (\ln X_{si})(\ln Y_{si}) - \frac{[(\sum_{i=1}^{n_2} \ln X_{si})(\sum_{i=1}^{n_2} \ln Y_{si})]}{n_2} \end{aligned}$$

= sum of cross products (24)

where the subscript si denotes the ith value from the secondary sample, $\ln X$ indicates natural logarithms of meter readings, $\ln Y$ indicates natural logarithms of vegetative weights, and $\sum_{i=1}^{n_2}$ summation of i values of a variable over the range 1 to n_2.

The relevant regression coefficients and comparative statistics are then calculated as in the linear model:

$$b = \frac{\mathrm{S}(\ln X \ln Y)}{\mathrm{SS}(\ln X)} = \text{regression coefficient} \tag{25}$$

$$a_1 = \overline{\ln Y_s} - b\overline{\ln X_s} = \ln a_2 = \text{constant} \tag{26}$$

$$\mathrm{SE}(\ln YX) = \sqrt{[\mathrm{SS}(\ln Y) - \frac{[\mathrm{S}(\ln X \ln Y)^2/\mathrm{SS}(\ln X)]}{n_2 - 2}}$$

$$= \text{standard error of estimate (residual error)} \qquad (27)$$

$$r^2 = \frac{[S(\ln X \ln Y)^2/SS(\ln X)]}{SS(\ln Y)}$$

$$= \text{coefficient of determination} \qquad (28)$$

$$C = S(\ln X \ln Y)/n_2 - 1 = \text{covariance}$$

Confidence intervals can be computed for estimated natural logarithms of weights using:

$$SE(\ln\hat{Y}) = SS(\ln YX)\sqrt{(1/n_2) + \frac{(\ln X - \overline{\ln X})}{SS(\ln X)}}$$

$$= \text{standard error of } \ln\hat{Y} \qquad (29)$$

Because the logarithms of vegetative weights and meter readings are meaningless in a practical sense, it is necessary to convert to arithmetic units. Because the linear model assumes normality of distribution of weights, whereas the logarithmic model assumes a log-normal distribution, it is necessary to apply a conversion factor when converting from logarithmic to arithmetic units with the following manipulations (Baskerville 1972):

$$\hat{Y}_a = e^{[\ln\hat{Y} + (SE(\ln\hat{Y})^2/2)]} \qquad (30)$$

Confidence intervals obtained with the logarithmic model are necessarily asymmetric after retransformation to arithmetic units; consequently, they must be determined using Student's t at the desired probability level for $\ln\hat{Y}$ before retransformation:

$$\ln\hat{Y} - t\ SE(\ln\hat{Y}) \leqslant \mu \leqslant \ln\hat{Y} - t\ SE\ (\ln\hat{Y}) \qquad (31)$$

where

$$\mathrm{Lim}(\hat{Y}) = \ln\hat{Y} \pm SE\ (\ln\hat{Y}) \qquad (32)$$

where the subscript a indicates arithmetic units, and raising e to a quantity denotes taking the natural antilogarithm of that quantity. Logarithmic limits are then individually retransformed to arithmetic units by a modification of (30):

$$\mathrm{Lim}_a(\hat{Y}) = e^{[\mathrm{Lim}(\hat{Y}) \pm SE(\ln\hat{Y})^2/2]} \qquad (33)$$

thus,

$$\mathrm{Lim}_{al}(\hat{Y}) \leqslant \mu_a \leqslant \mathrm{Lim}_{au}(\hat{Y}) \qquad (34)$$

where the subscripts u and l denote upper and lower limits, respectively, and where μ_a is the true vegetative mean for meter reading X and t is Student's t at any desired probability level with $n_2 - 2$ degrees of freedom.

Coefficients of determination are most frequently used to determine the quality of a regression relationship because they indicate the proportion of the variance in a given response variable that is explained by its regression on a given explanatory variable. Additional information is also obtained from the standard errors of estimate because they are based on deviations of observed values of both variables from their value predicted by the regression relationship (residual error). Consequently, two data sets with similar coefficients of determination may have widely different standard errors of estimate. However, it is difficult to compare standard errors of estimate between linear and logarithmic regression analyses because they do not estimate exactly the same quantity in the two models (coefficients of determination, being dimensionless, can be compared). Fortunately, Furnival (1961) has provided an index of fit called Furnival's index (I) that allows comparison of standard errors of estimate for each model. In the linear model, I and $SE(YX)$ are identical; for the logarithmic model we calculate I as follows:

$$I = SE(\ln YX)\,(e^{\overline{\ln Y}}) \qquad (35)$$

Consequently, the smaller the value of I, the better the model fits the secondary data. In addition, when comparing the adequacy of the linear and logarithmic models, the one producing the lower residual error provides the better fit, though it may not explain as much of the variation in the response variable.

Using the hypothetical data from the previous example, table 5 with its transformed data can be constructed. Then:

Table 5—Transformed hypothetical recording meter readings ($\ln X_{si}$) and vegetative weights ($\ln Y_{si}$) with corresponding squares and cross products

	Transformed data		Squares and cross products		
	$\ln X_{si}$	$\ln Y_{si}$	$\ln X_{si}^2$	$\ln Y_{si}^2$	$\ln X_{si} \ln Y_{si}$
	2.83	3.09	8.01	9.55	8.74
	3.33	4.25	11.09	18.06	14.15
	1.61	2.30	2.59	5.29	3.70
	2.40	3.14	5.76	9.86	7.54
	3.09	3.93	9.55	15.44	12.14
Totals ($\sum_{i=1}^{n_2}$)	13.26	16.71	37.00	58.20	46.27

$$n_2 = 5$$

$$\ln X_s = \frac{13.26}{5} = 2.65$$

$$\ln Y_s = 16.71/5 = 3.34$$

$$\mathrm{SS}(\ln X) = 37.00 - \frac{(13.26)^2}{5} = 1.83$$

$$\mathrm{SS}(\ln Y) = 58.20 - \frac{(16.71)^2}{5} = 2.36$$

$$\mathrm{S}(\ln X \ln Y) = 46.27 - \frac{[(13.26)(16.72)]}{5} = 1.96$$

and

$$b = \frac{1.96}{1.83} = 1.07$$

$$a_1 = 0.50$$

$$a_2 = 1.65$$

$$\mathrm{SE}(\ln YX) = \sqrt{\frac{2.36 - [(1.96)^2/1.83]}{3}} = 0.29$$

$$I = 0.29(e^{3.34}) = 8.18$$

$$r^2 = \frac{[(1.96)^2/1.83]}{2.36} = 0.89$$

$$C = 1.96/4 = 0.49$$

For a hypothetical meter reading of 12 we compute:

$$\ln\hat{Y} = 0.50 + 1.07(2.48) = 3.15$$

$$\mathrm{SE}(\ln\hat{Y}) = (0.29)\sqrt{(1/5) + [(-0.17)^2/1.83]}$$
$$= 0.13$$

Applying the necessary correction for nonnormality to convert to arithmetic units we compute:

$$\hat{Y}_a = e^{[3.5+(0.13^2/2)]} = 23.5$$

$$\mathrm{SE}(\hat{Y}_a) = \sqrt{e^{[2(0.13^2)+2(3.15)]} - e^{[(0.13^2)+2(3.15)]}}$$

$$= \sqrt{563.29 - 553.85} = 3.07$$

and

$$\mathrm{Lim}_u(\hat{Y}) = \ln(\hat{Y}) + t[\mathrm{SE}(\hat{Y})] = 3.15 + (0.13)(3.182) = 3.56$$

$$\mathrm{Lim}_l(\hat{Y}) = \ln(\hat{Y}) - t[\mathrm{SE}(\hat{Y})] = 3.15 - (0.13)(3.182) = 2.74$$

$$\mathrm{Lim}_{au}(\hat{Y}) = e^{[3.56+(0.13^2/2)]} = 35.46$$

$$\mathrm{Lim}_{al}(\hat{Y}) = e^{[2.74+(0.13^2/2)]} = 15.62$$

so that

$$15.62 \leqslant \mu \leqslant 35.46$$

for $P<0.05$ with 3 degrees of freedom (d.f.). This confidence interval is obviously too large, which results chiefly from the artificially low sample size leaving only 3 degrees of freedom. Normal sample sizes would yield at least 10 degrees of freedom, at which level $t_{0.05}$ is reduced from 3.182 to 2.228 in the example. The standard error should also decrease with larger sample sizes. For computational convenience, the example also contains some induced rounding error that has exaggerated derived values. Note also that the necessary asymmetry of the interval has been preserved. Expressing the interval as a percent of the mean therefore provides information about the uncertainty but says nothing about its shape.

Had we converted directly to arithmetic units, we would have obtained the following:

$$\hat{Y} = e^{(3.15)} = 23.3$$

$$\mathrm{SE}(\hat{Y}) = 1.13$$

and confidence interval of:

$$\mu = 23.3 \pm (3.182)(1.13) = 23.3 \pm 3.6 \text{ with 3 d.f.}$$

or

$$19.7 \leqslant \mu \leqslant 26.9 \text{ with 3 d.f.}$$

In this case, the difference in estimates of vegetative weights is small (1 percent). However, failure to use the conversion will always result in an underestimate, possibly as great as 20 percent (Baskerville 1972).

Phytomass Estimation—Standing vegetation biomass (phytomass) can be easily estimated by substituting mean meter readings from primary sampling for X in equations 2 and 17. These biomass estimates can be used to determine similarity in potential yield between pastures or study sites, and if pregrazing similarity is established, differences in phytomass can be used to estimate use by grazing animals.

First consider a hypothetical situation in which two sampled pastures have the primary data subsets shown in table 6 and the secondary data used in the previous example. Thus, the following quantities are obtained from equations 3-7 and 20:

$n_{p1} = n_{p2} = 10$ = sample size of each pasture

$\bar{X}_{p1} = \frac{300}{10} = 30$ = mean meter reading of pasture 1

$\overline{\ln X}_{p1} = \frac{33.81}{10} = 3.38$ = mean natural logarithms of meter readings of pasture 1

$\bar{X}_{p1} = \frac{310}{10} = 31$ = mean meter reading of pasture 2

$\overline{\ln X}_{p2} = \frac{34.14}{10} = 3.41$ = mean natural logarithms of meter readings of pasture 2

$$\mathrm{SS}(X_{p1}) = 9{,}360 - \frac{(300)^2}{10} = 360$$

= sum of squares of deviations in meter readings in pasture 1

$$\mathrm{SS}(X_{p2}) = 10{,}018 - \frac{(310)^2}{10} = 408$$

= sum of squares of deviations in meter readings in pasture 2

Table 6—Hypothetical meter readings, natural logarithms, and squared meter readings from two randomly selected pastures to determine similarity in standing phytomass

	Pasture 1			**Pasture 2**		
	Meter (X_{p1})	**lnX_{p1}**	**X^2_{p1}**	**Meter (X_{p2})**	**lnX_{p2}**	**X^2_{p2}**
	25	3.22	625	26	3.26	676
	30	3.40	900	29	3.37	841
	27	3.30	729	28	3.33	784
	28	3.33	784	30	3.40	900
	33	3.50	1,089	35	3.56	1,225
	36	3.58	1,296	34	3.53	1,156
	40	3.69	1,600	43	3.77	1,849
	37	3.61	1,369	39	3.66	1,521
	22	3.09	484	25	3.22	625
	22	3.09	484	21	3.04	441
Totals ($\sum_{i=1}^{n_p}$)	300	33.81	9,360	310	34.14	10,018

where the subscript p denotes the primary sample set, the subscripts 1 and 2 arbitrarily designate a first and second subset, respectively, and other variables are as described previously.

From the results of these equations we need to calculate the appropriate variances and error estimates in order to statistically compare these pastures to test the null hypothesis (H_o): the two pastures are indistinguishable with respect to average meter reading and, hence, potential vegetative yield. The following equations are required:

$$V(X_p) = \frac{\mathrm{SS}(X_p)}{n_p - 1}$$

= sample variance (36)

$$\mathrm{SD}(X_p) = \sqrt{\frac{\mathrm{SS}(X_p)}{n_p - 1}}$$

= sample standard deviation (37)

$$\mathrm{SE}(\bar{X}_p) = \sqrt{\frac{\mathrm{SS}(X_p)/n_p - 1}{n_p}}$$

= standard error of the mean of the meter readings (38)

$$V(\bar{X}_1 - \bar{X}_2) = \frac{[\mathrm{SS}(X_{p1}) + \mathrm{SS}(X_{p2})]}{(n_{p1} - 1) + (n_{p2} - 1)}$$

= pooled sample variance (39)

$$\mathrm{SE}(\bar{X}_{p1} - \bar{X}_{p2}) = \sqrt{\frac{2[V(X_{p1} - X_{p2})]}{n_p}}$$

= pooled standard error when $n_{p1} = n_{p2}$ (40)

$$\mathrm{SE}(\bar{X}_{p1} - \bar{X}_{p2}) = \sqrt{2\left[V(X_{p1} - X_{p2})\left(\frac{(n_{p1} + n_{p2})}{n_{p1} n_{p2}}\right)\right]}$$

= pooled standard error when $n_{p1} \neq n_{p2}$ (41)

$$t = \frac{(\bar{X}_{p1} - \bar{X}_{p2})}{\mathrm{SE}(\bar{X}_{p1} - \bar{X}_{p2})}$$

= Student's t with $(n_{p1} + n_{p2}) - 2$ d.f. (42)

From our example, we compute:

$$V(X_{p1}) = \frac{360}{9} = 40.0$$

$$V(X_{p2}) = \frac{408}{9} = 45.3$$

$$\mathrm{SD}(X_{p1}) = 6.3$$

$$\mathrm{SD}(X_{p2}) = 6.7$$

$$\mathrm{SE}(\bar{X}_{p1}) = 2.0$$

$$\mathrm{SE}(\bar{X}_{p2}) = 2.1$$

$$V(X_{p1} - X_{p2}) = \frac{(360 + 408)}{18} = 42.7$$

$$\mathrm{SE}(\bar{X}_{p1} - \bar{X}_{p2}) = \frac{2(42.7)}{10} = 2.9$$

$$t = \frac{(30.31)}{2.9} = -0.34 \text{ with 18 d.f.}$$

Because t is two-tailed for our purposes, the sign can be ignored. From t tables we see that $t_{0.05}$ with 18 d.f. = 2.101, so H_o cannot be rejected at the 95 percent level.

If confidence intervals (for whatever level of probability) are desired for each of the mean meter readings, they are easily calculated as:

$$\mu_p = \bar{X}_p \pm \mathrm{SE}(\bar{X}_p)t \text{ with } n-1 \text{ d.f.} \tag{43}$$

where μ_p indicates the true mean meter reading of a primary subsample. From our example, the following 95 percent confidence limits are obtained:

$$\mu_{p1} = 30.0 \pm 2.0(2.262) = 30.0 \pm 4.5 \text{ with 9 d.f.}$$

$$\mu_{p2} = 31.0 \pm 2.1(2.262) = 31.0 \pm 4.8 \text{ with 9 d.f.}$$

The mean meter reading for each site is inserted for X in either regression model to obtain estimates of mean vegetative weights for the 2-ft^2 plot sensed by the herbage meter. Because the values substituted are mean meter readings rather than individual meter readings, and therefore have their own variance, the simple equation for the variance of the estimated mean vegetative weight cannot be used directly. For the linear model, Cochran (1963) provides a modified equation for the calculation of the variance of weights from double sampling estimation. This variance is defined as:

$$V(\hat{Y}_m) = \mathrm{SE}(YX)^2 \left\{ \left[(1/n_{1s}) + \frac{(\bar{X}_p - \bar{X}_s)^2}{\mathrm{SS}(X_s)} \right] + \left[\frac{[V(Y_s) - \mathrm{SE}(YX)^2]}{n_p} \right] \right\}$$

$$= \text{variance of estimated } Y \text{ from double sampling} \tag{44}$$

Therefore:

$$\mathrm{SE}(\hat{Y}_m) = \sqrt{V(\hat{Y}_m)}$$

$$= \text{standard error of estimated } Y \text{ from double sampling} \tag{45}$$

with confidence intervals calculated as before:

$$\mu = \hat{Y} \pm t\,\mathrm{SE}(\hat{Y}_m) \tag{46}$$

for the desired probability level.

Because the logarithmic model is linear after transformation of the variables, the following analogous definitions are derived:

$$V(\ln\hat{Y}_m) = \mathrm{SE}(\ln YX)^2 \left\{ \left[(1/n_{2s}) + \frac{(\overline{\ln X_p} - \overline{\ln X_s})^2}{\mathrm{SS}(\ln X_s)} \right] + \left[\frac{V(\ln Y_s) - \mathrm{SE}(\ln YX)^2}{n_p} \right] \right\} \tag{47}$$

$$\mathrm{SE}(\ln\hat{Y}_m) = V(\ln\hat{Y}_m) \tag{48}$$

where the subscript m denotes an estimate using a mean meter reading.

Conversion of $\ln\hat{Y}_m$ is accomplished with definition (30), substituting $\mathrm{SE}(\ln\hat{Y}_m)$ for $\mathrm{SE}(\ln\hat{Y})$, and confidence intervals are determined using definitions (31) through (34), inclusive.

From our previous example, the following results are obtained:

Linear model:

$$\hat{Y}_{mp1} = 2.3(30.0) + 2.3 = 66.7$$

$$\hat{Y}_{mp2} = 2.3(31.0) + 2.3 = 69.0$$

$$\mathrm{SE}(\hat{Y}_{mp1}) = (7.7)\sqrt{\left[(1/7) + \frac{(30.0-11.9)^2}{718.9}\right] + \left[\frac{(465.4)-(7.7)^2}{10}\right]}$$

$$= 8.7$$

$$\mathrm{SE}(\hat{Y}_{mp2}) = (7.7)\sqrt{\left[(1/7) + \frac{(31.0-11.9)^2}{718.9}\right] + \left[\frac{(465.4)-(7.7)^2}{10}\right]}$$

$$= 8.9$$

and 95 percent confidence limits about the true vegetative weights per 2 ft^2 in each site would be:

$$\mu_{p1} = 66.7 \pm (8.7)(2.262) = 66.7 \pm 19.7 \text{ with 9 d.f.}$$

$$\mu_{p2} = 69.0 \pm (8.9)(2.262) = 69.0 \pm 20.1 \text{ with 9 d.f.}$$

Logarithmic model:

$$\ln\hat{Y}_{np1} = 0.50 + 1.07(3.38) = 4.12$$

$$\ln\hat{Y}_{np2} = 0.50 + 1.07(3.41) = 4.15$$

$$\mathrm{SE}(\ln\hat{Y}_{mp1} = (0.29)\sqrt{\left[(1/5) + \frac{(3.38-2.65)^2}{1.83}\right] + \left[\frac{(0.59)-(0.29)^2}{10}\right]}$$

$$= 0.30$$

$$\mathrm{SE}(\ln\hat{Y}_{mp2}) = (0.29)\sqrt{\left[(1/5) + \frac{(3.41-2.65)^2}{1.83}\right] + \left[\frac{(0.59)-(0.29)^2}{10}\right]}$$

$$= 0.34$$

Note that the mean of the natural logarithms of the primary meter readings is used rather than the natural logarithm of the mean meter readings. This is necessary to adjust for the assumption of non-normality discussed previously. The conversion to arithmetic units proceeds as before:

$$\hat{Y}_{mp1} = e^{\left[4.12 + \frac{(0.30)^2}{2}\right]} = 64.4$$

$$\hat{Y}_{mp2} = e^{\left[4.15 + \frac{(0.34)^2}{2}\right]} = 67.2$$

Confidence limits must be determined first within transformed variables as follows:

$$\mathrm{Lim}_u(\ln\hat{Y}_{np1}) = \ln\hat{Y}_{np1} + t[\mathrm{SE}(\hat{Y}_{mp1})]$$

$$= 4.12 + (0.30)(2.262) = 4.80$$

$$\mathrm{Lim}_l(\ln\hat{Y}_{np1}) = \ln\hat{Y}_{np1} - t[\mathrm{SE}(\hat{Y}_{mp1})]$$

$$= 4.12 - (0.30)(2.262) = 3.44$$

and

$$\mathrm{Lim}_u(\ln\hat{Y}_{np2}) = \ln\hat{Y}_{np2} + t[\mathrm{SE}(\hat{Y}_{mp2})]$$

$$= 4.15 + (0.34)(2.262) = 4.92$$

$$\mathrm{Lim}_l(\ln\hat{Y}_{np2}) = \ln\hat{Y}_{np2} - t[\mathrm{SE}(\hat{Y}_{mp2})]$$

$$= 4.15 - (0.34)(2.262) = 3.38$$

for $P<0.05$ with 9 d.f. and where the subscripts u and l denote the upper and lower limits, respectively.

At this point, it is acceptable to use definition 33 to produce the required asymmetric confidence intervals:

$$\mathrm{Lim}_u(\hat{Y}_{np1}) = e^{[4.80+(0.30^2/2)]} = 127.1$$

$$\mathrm{Lim}_l(\hat{Y}_{np1}) = e^{[3.44+(0.30^2/2)]} = 32.6$$

and

$$\mathrm{Lim}_u(\hat{Y}_{np2}) = e^{[4.92+(0.34^2/2)]} = 145.2$$

$$\mathrm{Lim}_l(\hat{Y}_{np2}) = e^{[3.38+(0.34^2/2)]} = 31.1$$

Therefore

$$32.6 \leqslant \mu_{mp1} \leqslant 127.1$$

and

$$31.1 \leqslant \mu_{mp2} \leqslant 145.2$$

for $P<0.05$ with 9 d.f. Once again, the confidence intervals are wide because of the artificially small sample size used in the example and because of accumulated rounding errors.

The estimated vegetative weights obtained by the above manipulations represent the average vegetative weight within the sensing field of the capacitance meter. Because weights were collected in grams, and the meter samples a 2-ft^2 area, the above weights were 64.4 g/2 ft^2 and 67.2 g/2 ft^2, respectively. Conversion to pounds per acre is accomplished by multiplying directly by 48. Because these conversion factors are constants (without sampling error) they can also be multiplied by the confidence limits to obtain relevant confidence intervals for phytomass estimates. From our example:

$$\begin{aligned} \text{Phytomass, site 1} &= 64.4(48) \pm 44.8(48) \\ &= 3{,}091 \pm 2{,}150 \text{ lb/acre} \\ \text{Phytomass, site 2} &= 67.2(48) \pm 53.2(48) \\ &= 3{,}226 \pm 2{,}554 \text{ lb/acre} \end{aligned}$$

Difference in standing phytomass between the two sites is:

$$\left(\frac{67.2-64.4}{67.2}\right)(100) = \left(\frac{3{,}226-3{,}091}{3{,}226}\right)(100)$$

$$= \left(\frac{3{,}877-3{,}716}{3{,}877}\right)(100) = 4 \text{ percent}$$

Note that phytomass need not be determined to obtain the percent difference in yield; any difference in estimated weights can be used for this purpose alone.

If weights were collected in ounces so that the initial result produced weights in ounces per 2 ft^2, the factor for converting to phytomass is 1,360.777 for a result in pounds per acre.

Computer Processing—A variety of commercially available software packages for microcomputers will perform linear and nonlinear regressions. In many cases, however, these two types of regression must be performed with separate packages. When they are available on the same package, the necessary statistics to adequately compare the relative efficiency of each model are frequently not included. The need to perform double sampling with regression, the need to predict values of the response variable from the mean values of primary sets of explanatory variables with corrections for non-normality and with assumptions appropriate to the logarithmic model, and the desire for computations of confidence statistics add to the need to employ several software packages. This situation clearly leads to inefficiency in data processing and barriers to effective information transfer between resource management professionals.

One software package has been developed by us for comprehensive analysis of biomass and yield differential between sites (see appendix 4). It allows double sampling as well as comprehensive analysis of up to 23 auxiliary habitat variables. The possibility of regressing several sets of paired variables is also included. Riparian habitat data are simply entered into the computer from a mass storage device, and the program automatically performs both regression analyses and phytomass and yield differential estimation using algorithms based on the mathematical relationships discussed previously. Little hands-on work is required of the data processor other than entering the data and the desired statistical confidence level. The flow pattern and relationships of the subroutines are pictured in appendix 5.

Expansion—This software package was principally designed for the livestock-fishery interaction studies currently being conducted by the Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. However, potential expansion of the basic program should cover a variety of potential double-sampling studies. Variables have been dimensioned to allow the comparison of up to 10 data sets of 25 habitat or resource variables each, and regression analyses can be conducted on any two of the 25 individual habitat or resource variables. Although outputs are made in terms of phytomass and units appropriate to range analyses, print statements can be made, by an experienced programmer, to reflect whatever sorts of data are being evaluated. For example, an investigator could use the logarithmic routine to regress rainbow trout length versus rainbow trout weight from a secondary sample set to estimate individual or average weights from a large primary data set containing only trout lengths. This would require only statements to bypass the linear regression routine, eliminating the conversion of vegetative weights to pasture yield, and modifying the print statements to output appropriate terms.

Portability—The program supporting this chapter (appendix 5) was written on a Hewlett-Packard 9845T. The HP-9845T is a competent machine, but it is several years old. Agencies and persons purchasing new machines will most likely be purchasing hardware with considerably greater flexibility. We are adapting this program for use on an IBM-PC with PC-DOS, which will be much more suitable to modern machines, especially those using PC or MS-DOS. (For additional information, please contact the senior author.) In the meantime, however, it seems prudent to include a few comments, chiefly syntactical, for those who may wish to convert this program to IBM or similar format.

Modern IBM microcomputers incorporate BASIC language interpreters with many extended features. While this improves programming on a given machine, it can reduce portability. Table 7 contains a brief list of BASIC statements used in HERB-2 and IBM equivalents. In general, transferring the program to another machine should be fairly straightforward provided the programmer knows the idiosyncrasies of the target computer, and has sufficient main memory.

Table 7—Some important HP-9845 BASIC and IBM advanced BASIC statement equivalents

HP-9845	IBM BASIC
CLEAR	CLS
MAT(VAR) = ZER	No equivalent, DIM statement zeros array
PRINT USING	PRINT USING
a. with image statements, one code line per printed lines	a. with image statements to a device using several code line and suppressing line feed where needed
b. with IMAGE line	b. no equivalent
IMAGE	No equivalent
PRINT LIN(#)	PRINT
	a. repeated desired number of lines (#)
	b. LOCATE (screen position)
LET	LET (not required in assignment statements)
PRINTER is (DEV#)	PRINT to screen, LPRINT to default printer
PRINT PAGE	PRINT
LINPUT	INPUT
ASSIGN#(n) to FILENAMES	OPEN#(n) FOR (I/O/APPEND) or FILENAMES
READ#(n)	INPUT#(n)
REDIM	No equivalent
SCRATCH	NEW

RIPARIAN COMMUNITY CLASSIFICATION

Riparian areas are important islands of diversity within extensive forest and rangeland ecosystems. Abundant water, forage, and other amenities attract a proportionately greater amount of use and conflict in riparian areas than their small aggregate area would indicate. These areas are thus receiving increasing attention from land managers in the Western United States.

Riparian areas often support complex mosaics of plant communities, associated with soil and hydrologic variation. The purpose of classification into habitats—defining taxonomic units that comprise closely similar communities—is to segment and describe this diversity as a basis for sound management. The constituent communities of a taxonomic unit are predicted to respond to management in nearly the same way. Units are defined at a level of detail suitable for multidisciplinary applications, but not in such great detail that the classification is difficult to use.

Riparian habitats are generally characterized by environmental processes markedly different from those that prevail on upland sites. For this reason, many western forest and rangeland classification concepts are not valid in riparian areas. The remainder of this section highlights some of these differences and presents some key concepts underlying riparian classification.

Riparian areas are geomorphically active, with periodic natural disturbances affecting soil and hydrologic characteristics. Water tables may be subject to fluctuation at relatively frequent intervals. At any one location, succession seldom proceeds to a long-term (several hundred years) stable end point. Disturbances that interrupt succession generally recur before such an end point can be reached. Therefore, the concept of "climax," as implied in forest and rangeland habitat classifications, is generally not applicable to riparian classifications.

The fundamental unit of riparian classification is the community type, defined by present rather than potential (climax) vegetation. However, riparian community types represent more than current floristic units. These types can be fairly well correlated with soil and environmental characteristics. Inferences can be drawn regarding environmental gradients and successional relations between types. Therefore, riparian community types represent "types of habitat" but cannot be termed "habitat types." The latter term refers to areas of land capable of supporting long-term stable (climax) communities, a situation seldom realized in riparian areas.

Grouping of community types can be done based on similar characteristics that affect management or use. Western forest and rangeland habitat types are grouped into "series" that share the same potential climax overstory. Grouping of riparian types may be based on common overstory or understory. The latter seems to have more utility because herbaceous layers are generally better than overstory as indicators of current soil-hydrologic properties that affect management decisions.

Methods used to develop a riparian classification center on a concomitant study of vegetation, soil, and environmental factors (Poulton and Tisdale 1961). The following discussions focus on specific field and office methods employed successfully in western Wyoming (Norton and others 1981) and central Idaho (Tuhy and Jensen 1982). Emphasis is placed on vegetation analyses because floristic data are used to generate and name the community types.

Field Methods

Field sampling provides the raw data upon which the classification is based. Field methods involve the following activities:

1. Within the overall study area, identify a range of subareas to receive sampling emphasis.
2. In each identified subarea, select individual communities or stands for sampling.
3. In each selected community, locate a certain type of sample plot.
4. In each plot, record information relevant for floristic clustering and soil/environmental correlation.

Subarea Identification—When developing a classification over a broad geographical area, it is not possible to observe or sample every riparian habitat. Within a large study area it is necessary to select subareas, such as certain stream drainages or other wetlands, for sampling emphasis. Streams and wetlands should be chosen to encompass the variation in vegetative, geologic, soil, and environmental characteristics over the area of concern. The selection process is aided by maps, aerial photos, ground reconnaissance, and conversations with people who know the area. This process is done once at the start of the project, though decisions may be modified several times as field work progresses.

Schedules should be formulated, insofar as logistics allow, so that sampling occurs when vegetation is at its optimum phenological stage. "Optimum" here refers to full leaf and flower or fruit. Generally, sampling will progress from lower to higher elevations during the course of a field season.

Sample Site Selection—Within each identified subarea, distinct vegetation communities are selected for sampling. The approach of "subjectivity without preconceived bias" (Mueller-Dombois and Ellenberg 1974) has been used successfully for this purpose.

Communities are subjectively selected for sampling rather than by systematic or random (objective) methods. The selection is thus based on judgment of the investigators. To be sampled, communities must meet two criteria:

1. The community should be homogeneous. This is generally a visual determination, avoiding obvious ecotones and changes in vegetative composition or structure.
2. The community should occupy an area at least three times that of the plot (see following section). This minimizes influences from adjacent communities.

Investigators begin by sampling each community encountered in each identified subarea. As field work progresses through a number of locations, investigators recognize recurring community patterns. Replicate examples of closely similar communities are sampled. The investigators formulate hypotheses that these recurring communities will form the basis for community type units.

Such hypotheses can bias subsequent decisions of what or where to sample. Sample site selection "without preconceived bias" means that communities are not rejected if they do not conform to the classification system hypothesized to date. Investigators should accept new working hypotheses for the classification as soon as further knowledge suggests a modification or change.

As work progresses and classification concepts emerge, frequent and widespread communities need not be sampled seemingly forever. However, minor community differences may be significant and should not be ignored.

Nature of Sample Plots—Exact location of a plot within a community should depict the "central tendency" of that community. Transitional areas near community borders are best avoided.

Existing riparian classifications have used the metric system, with a 50-m^2 macroplot in the form of a 5- by 10-m rectangle. This size and shape was selected because:

1. The 50 m^2 is equal to or greater than the minimal area for shrub and herb strata as suggested by Mueller-Dombois and Ellenberg (1974). This area is generally too small for sampling overstory tree strata, but these are infrequent in riparian areas. Where mature trees do occur, plot sizes of 375 m^2 or 500 m^2 may be used to conform with forest sampling methodology in the West (provided plots are homogeneous and little-influenced by adjacent communities).
2. As small a representative area as possible is desired. This is so that plots fit in communities that are arranged in intricate mosaics, without encountering heterogeneity or ecotones.
3. Plot shape is rectangular in response to the common elongation of riparian communities parallel to a stream channel. In cases of extreme elongation, such as a streambank fringe, the standard shape (but not area) may be modified.

Plot Data—Constructing a classification from a series of sample plots requires information relevant for clustering. Floristic grouping requires that in each plot at least the following information be recorded:

1. A complete plant species list. Unknown specimens are usually collected for later identification. A set of voucher (truthing) specimens should also be collected during the project.
2. A quantitative factor that describes each species' role in the community. Canopy cover is the most common factor used. Frequency and density are other factors that may be applicable.

Canopy cover for each species is generally estimated visually within the 50-m^2 macroplot. Such estimates are easy to obtain and easy to "see" when using the classification to identify an unknown community. A series of microplots 20 by 50 cm each can occasionally be nested in the macroplot to calibrate ocular cover estimates.

The height of each species, or at least of each stratum, may be useful in defining community types. Production and use measurements may be useful for management, but they are not vital to build the classification.

A number of environmental characteristics are also recorded for each plot. These include elevation, slope, aspect, and valley-bottom width (where applicable). Also noted are physiognomy, disturbance, and types of adjacent communities. Soil investigations and water-table measurements also occur, and their description appears in the subsequent section on riparian soils.

At any particular sample site there is a tradeoff between rapidity and amount of information gathered. For classification purposes, it is generally more useful to analyze a greater number of samples in less detail than to analyze a few in great detail.

Office Methods

The classification is derived using office procedures that manipulate and synthesize field data. After initial plant taxonomy work, the methods center on the derivation of community types via floristic clustering techniques. Final considerations include synthesis with environmental characteristics, nomenclature, and report preparation.

Plant Identification—Plants must be correctly identified before any data tabulation or manipulation occur. Unknown specimens should be identified to species if possible. Vegetative specimens may be identifiable to genus only. Voucher specimens should also be confirmed.

Taxonomic problems are noted at this time. These are usually mentioned in the final classification report.

Floristic Clustering—Sample plots are grouped into units that exhibit similar vegetative composition and structure. The initial grouping is generally based on classification hypotheses formulated during field sampling.

Subsequent tabular display of floristic data can more clearly show similarities and differences between plots. Association tables used for this purpose (see Mueller-Dombois and Ellenberg 1974, pp. 177-193) portray the magnitude (such as canopy cover) of all species within a series of plots. By shifting species and plots (rows and columns) in the table, investigators can visually identify the groups of similar plots. Recent computer programs have made table manipulation much easier than tedious handwritten techniques.

Mathematical cluster analysis procedures may be used to refine or validate the results of tabular classification, or perhaps both. Cluster analysis involves several steps:

1. Reduce the data set by removing scarce or incidental species from consideration. For example, investigators may disregard species with less than 5 percent overall constancy, or those that were never observed with more than 1 percent canopy cover, or both. There are times, however, when species should not be disregarded, such as occurrence of treatment and endangered species or occurrence of "ice cream" plants used heavily by livestock.
2. Decide whether clustering will be done using species presence-absence data or quantitative data (such as canopy cover). Quantitative data usually require some type of transformation so that large values do not overwhelm consistent differences in smaller values.
3. Construct a matrix of similarity or dissimilarity, using any of a substantial number of coefficients. The matrix shows the level of similarity (or dissimilarity) between every plot-pair in the data set.
4. Then use any of a number of clustering procedures to generate a dendrogram, showing at what level of similarity (or dissimilarity) sample-plot clusters are connected. Marshall and Romesburg (1977) developed a polythetic agglomerative procedure named CLUSTAR that has been used in previous riparian classifications.

Although cluster analysis employs objective, mathematical techniques, each step listed above requires decisions that may be subjective on the part of the investigator. Cluster analysis is a tool able to show groupings that may not be apparent during association table procedures. However, final classification decisions rest with the ecological expertise and field experience of the investigators.

Final Considerations

The synthesis of floristic units with soil and environmental characteristics defines the final community types. Types should not be formally recognized unless they are represented by at least four, but preferably 10 or more, sample plots. Communities that recur infrequently within the area of concern should be considered as incidental. Community recurrence is vital to recognizing classification units. This is the major reason for sampling a large number of communities in just enough detail to enable their classification.

Once the final community types are defined, they must be named. Nomenclature is almost exclusively based on vegetative indicator species in shrub (if present) and herbaceous strata.

Indicator species are often, but not always, the dominants in their respective strata. An indicator species, particularly in the herbaceous layer, should have both high constancy and high fidelity. A species with high constancy but lower fidelity (that is, more widespread) is less desirable for naming community types, but may need to be used.

Riparian classifications are ultimately tools for managing riparian areas. A report or manual to be used by management personnel is the necessary end product of all the above methods. At a minimum such a document will contain: (1) keys to initially identify unknown communities; (2) descriptions of each community type that include floristic, environmental, and management implications; and (3) vegetative synthesis tables that show species constancy and average cover in each community type.

Several ecologically based riparian classifications have been completed in the Intermountain West. Work continues toward the goal of classifying riparian habitats throughout the Intermountain Region of the USDA Forest Service. Knowledge gained from such classifications can foster the sound management of these small but productive and sensitive habitats.

RIPARIAN SOILS

Interpretations regarding the genesis, function, and dynamics of riverine riparian ecosystems include general concepts of flood plain geomorphology, soil genesis, soil morphology, and soil taxonomy common to riparian positions in the Northern Rocky Mountain Physiographic Province (Arnold 1975). These concepts stem from both the scientific literature and intensive investigations of riparian ecosystems in mountainous regions of Utah (Jensen 1981), Wyoming (Tuhy and Jensen 1982; Jensen 1984), and Idaho (Jensen and Tuhy 1982). Although the concepts are common to riverine riparian positions in the Northern Rocky Mountain Physiographic Province, they may not be consistent across provincial boundaries.

Riverine riparian ecosystems are defined as the composite of terrestrial subsystems spanning from the apparent bank of stream channels in medial positions of valley bottoms to the lower edge of upland positions. The definition excludes permanently flooded (aquatic) classes of the Palustrine System as defined by Cowardin and others (1979). A useful working definition for riparian soils is the collection of polypedons distinguished by characteristics indicative of saturation by ground water during a significant period of the growing season within the rooting depth of native vegetation. The definition logically includes terrestrial areas supporting obligate phreatophyte plant species.

Soil morphology is a response to climatic, hydrologic, and biologic processes acting upon geologic material. Geomorphic position, relative to environmental gradients, is primarily responsible for determining the rate and degree to which these processes influence the soil system. The approach to subsequent development is to elucidate the processes responsible for the genesis of soil and the causative relationships resulting in spatial distribution of contrasting soil types in riparian areas.

Flood Plain Geomorphology

The genesis of fluvial valley bottoms is primarily a response to fluventic processes. The "energy signature" of a stream may be conceptualized as a "power line" concentrated as a force directed parallel to the ground surface over an elongated, often sinuous area (Kangus 1978). The energy potential of such a system is a function of stream discharge and the difference in elevation between two points.

The longitudinal slopes of streams decrease as an inverse function of discharge (Bloom 1978). In valley systems, discharge generally increases in a downstream direction as a result of the intersection of lower order tributaries, runoff from contiguous uplands, and subsurface discharge from alluvial aquifers. Consequently, the slopes of streams generally decrease in a downstream direction.

The competence of a stream refers to the maximum size particle that it will move. The competence of a fluvial system increases as a function of flow velocity. A small, fast-flowing stream can move a relatively large particle. While the competence of such a stream is great, the amount of material transported is small. Variability in the competence of stream and flood waters results in a sorting of fluvial sediments from coarse to fine in a direction of decreasing flow velocity.

Streams move most of the annual sediment load during short intervals of peak discharge resulting from snowmelt, rainfall, or both. The sediment-carrying capacity of a stream increases exponentially as a function of discharge. A tenfold increase in discharge may increase the sediment load a hundredfold to a thousandfold. A large, slow-moving stream may carry a large quantity of suspended sediments, although its competence is low.

Flow characteristics of fluvial systems in western montane regions are often modified by the engineering habits of beavers. Flow velocity, competence, and channel geometry are affected. Beaver channels may extend the aquatic environment to distal portions of the valley bottom. The still or slowly moving water of beaver ponds and channels favors proliferation of aquatic or emergent vegetation, or both, and the deposition of relatively fine-grained sediments.

Other factors affecting the hydraulic gradients of fluvial systems and subsequent geomorphic development of valley bottom positions include mass wasting of contiguous valley slopes, debris jams, and human engineering practices.

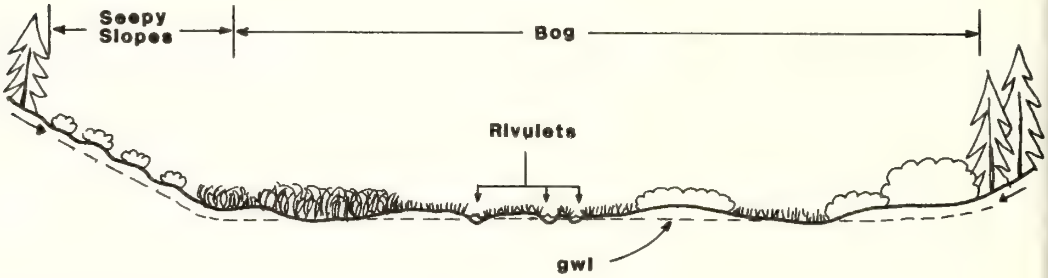


Figure 9—General form of headwater positions.

Valley Bottom Conformations—Three general geomorphic forms of riverine valley bottoms have been identified in the Northern Rocky Mountain Physiographic Province (Tuhy and Jensen 1982): glaciated headwaters, narrow V-canyons, and broad valleys. (More detailed descriptions of the typical composition and structure of geomorphic forms are discussed later under soil morphology.)

Glaciated headwaters constitute the initial convergence of drainage sources for many montane streams. General positions constituting riparian ecosystems in glaciated headwaters include seepy slopes and bogs. Alternatively, the headwaters of some drainages may have the form of narrow V-canyons. Seepy riparian positions in glaciated headwaters may extend considerable distances up moderate to steep valley slopes and are normally sustained by dispersed subsurface flow originating from snowmelt or discharge from bedrock aquifers. Seepy slopes grade to broadly concave, nearly level bog positions. Surface flow in bogs is often limited to small rivulets. A general schematic of headwater positions is presented in figure 9.

Narrow V-canyons are associated with steep-gradient, low-order stream segments. Streams in these positions may be actively downcutting into consolidated geologic material. Upstream segments of narrow V-canyons may be headcutting toward headwater positions of drainages, while downstream segments may be approaching the graded condition characteristic of broad-valley streams. Valley walls rise abruptly and confine channels to narrow, relatively straight stretches. Riparian areas in V-canyons are generally restricted to narrow bands contiguous to stream channels. The general form of narrow V-canyons is illustrated in figure 10.

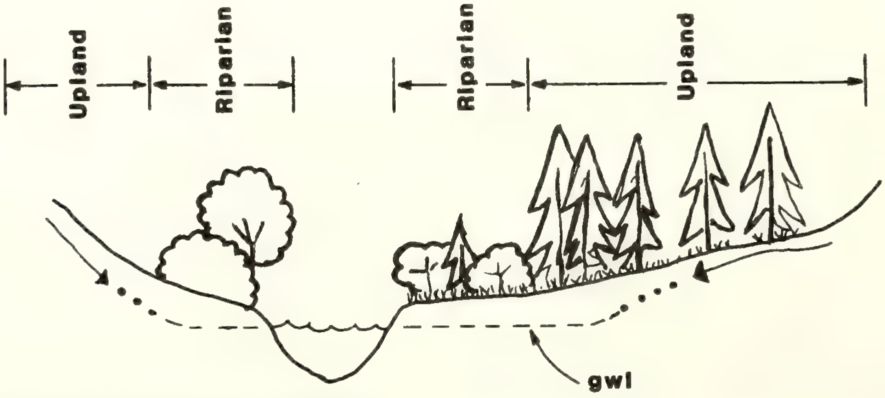


Figure 10—General form of V-canyons.

Broad-valley systems are generally associated with sinuous, low-velocity streams characterized by seasonal overbank flooding. Seasonal flooding and the movement of stream channels across broad valleys result in a high degree of geomorphic diversity in the form of stream bars, levees, low-lying wetlands, and riparian meadows. The apparent dominant sources of alluvial ground water in broad-valley systems are upstream alluvial positions. Surface and subsurface drainage from contiguous sideslopes may also contribute significant volumes of water, especially during runoff. Ground water level (gwl) in broad-valley systems is normally approximated by stream stage elevation during periods of base flow. The general form of broad-valley systems is illustrated in figure 11.

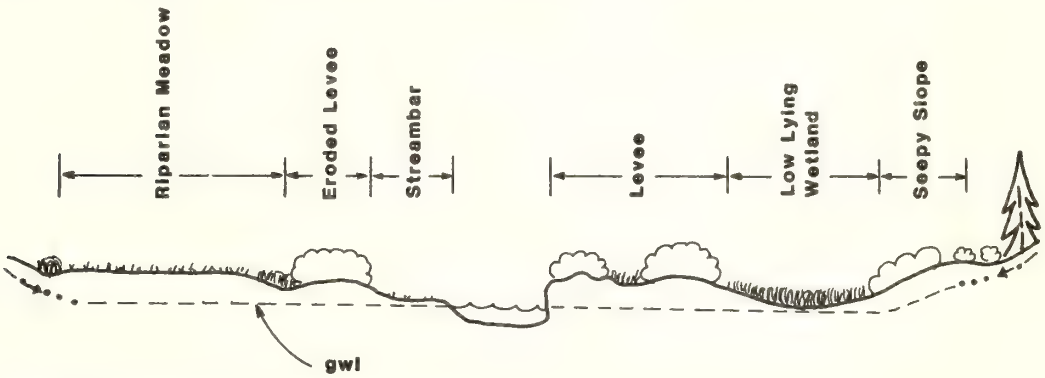


Figure 11—General form of broad-valley systems.

Distribution of Sediments—The distribution of mineral sediments comprising alluvial positions is a response to three general modes of depositions: sedimentation from adjacent upland positions, vertical accretion, and lateral accretion. Erosion of soil and mineral materials from residual upland positions constitutes the initial source of flood plain sediments. Sediments may be transported to alluvial positions under the influence of water, gravity, or wind. Alluvial (water) transport dominates in broad-valley systems with shallow to moderately steep sideslopes and at the intersection of lower order tributaries. Alluvial sedimentation commonly results in smooth, convex topography that gradually dips toward the medial line of the valley bottom. Colluvial (gravity) deposition is normally limited to narrow, V-canyon positions where streams are downcutting into bedrock materials. Colluvial deposition results in short, steep transitions from the stream channels to uplands. Colluvial sediments normally include angular rock fragments eroded from contiguous uplands. The influence of eolean (wind) sedimentation is generally not apparent in flood plain positions in the Northern Rocky Mountain Physiographic Province.

Vertical accretion occurs when stream discharge becomes greater than channel capacity and bank overflow occurs. The shallow, low-velocity sheet of floodwater has little competence relative to channel flow. Sediments are deposited on the flood plain and are generally sorted from coarse to fine in a direction away from the channel axis. Depositional events associated with floodwaters of contrasting competence result in the deposition of distinct strata of contrasting texture and coarse-fragment content. Vertical accretion is most apparent in broad-valley systems associated with low-gradient, sinuous streams.

Lateral accretion is a redistribution of sediments deposited by vertical accretion or by sedimentation from adjacent upland positions. As a stream meanders across its flood plain, channel banks are undercut and eroded. Fluvial erosion is most effective opposite convex point-bars where banks are most nearly perpendicular to the direction of streamflow. As a bank is undercut and collapses, sediment is carried downstream and redeposited. Lateral accretion is a principal process of channel modification and lateral movement across the flood plain in broad-valley systems. Normally, little evidence of lateral accretion is evident along riparian systems associated with streams entrenched in narrow, V-canyon positions. The effect of lateral accretion is to obliterate evidence of vertical accretion.

The accretion of organic matter (OM) is an important factor determining microtopography and drainage characteristics in some riparian ecosystems. The process is most apparent in headwater positions where dispersed drainage maintains conditions conducive to OM proliferation and limits the degree of OM mineralization. Deep accumulations of OM, often stratified with layers of mineral sediments, are common throughout headwater positions and, less extensively, in broad-valley positions. Major sources of OM are bryophytes and fibrous roots of herbaceous plant species.

Soil Genesis

Soil is a product of ecosystem processes acting upon environmental states. A process represents an energy flux into or through an open system. In this case, the system is a thin, unconsolidated surface mantle upon which most terrestrial life is dependent.

Processes affecting the soil system include erosion and deposition, organic matter production and mineralization, flocculation and dispersion of ped structure, physical weathering and sedimentation, eluviation and illuviation, oxidation and reduction, and dissolution and precipitation of soluble minerals. The degree to which processes affect a system is influenced by the state of the system. The state of a system is defined by its composition, position, temperature, and pressure. By assuming relatively consistent temperature and pressure, a description of state reduces to that of composition and position.

The composition of soil in riparian areas includes both mineral and organic materials. Water is conventionally considered a distinct component integral with the soil system. The texture and coarse-fragment content of mineral material may vary spatially on the site level of resolution and vertically within a single profile. The distribution of sediments is in response to spatial and temporal variability in alluvial transport mechanisms. The mineral composition is further determined by geologic parent material that may vary at local or regional scales. Organic matter content and form varies in response to complex interactions between biologic, soil, and hydrologic factors.

The position of materials relative to environmental gradients is important in determining the degree to which processes affect soil genesis. The position within valley bottoms is important where processes originate from point or line sources (erosion and deposition) and where the composition of the system is spatially heterogeneous (such as is most common in natural systems). In riparian ecosystems, the position of soils relative to fluvial and alluvial ground water geometries is the dominant factor controlling the rate, degree, and form of soil genesis.

Stream bars may be considered both the initial state from which soil genesis proceeds and the limit to which it may regress. Processes normally associated with progressive development are deposition of sediments and OM production. Processes that determine the form of subsequent development include eluviation, illuviation, oxidation, reduction, dissolution, precipitation, flocculation and dispersion of ped structure, and the degree of OM decomposition and mineralization. Erosion is generally associated with regressive development.

Soil morphology is a study of the form, composition, and structure of soil. A history of processes affecting riparian systems is well-documented in the morphology of soil.

Soil Morphology

The morphology of riparian soils often reflects both the mode of sediment deposition and the form of in situ pedogenesis. Pedons characterized by vertical accretion generally occupy an intermediary position between channel and upland positions. Morphological characteristics indicative of vertical accretion are (1) distinct horizons of contrasting textural classes, (2) OM content of mineral horizons that decreases irregularly with depth, and (3) buried organic horizons.

Pedons characterized by lateral accretion are generally adjacent to the channel axis but may extend to the periphery of the valley bottom where stream channel positions have been displaced over time. Morphologic characteristics indicative of lateral accretion are (1) relatively thick horizons containing rounded rock fragments, (2) low OM content in mineral horizons that either decreases regularly with depth or is homogeneous throughout the stratum, and (3) the absence of buried organic or dark mineral horizons formed at the surface within the depth affected by lateral accretion.

In situ pedogenesis requires some degree of temporal stability. In time, in situ development may mask those characteristics associated with vertical and lateral accretion. In situ pedogenesis is characterized by (1) an accumulation of OM in surface horizons and a regular decrease in OM content deeper in the soil profile, (2) moderate to strong ped structure in surface horizons resulting from flocculation of mineral sediments, (3) mottles resulting from oxidation and reduction of soil mineral material, (4) eluviation and illuviation of mineral and organic components in response to percolation of surface water, and (5) dissolution or precipitation of soluble minerals by infiltrating surface water or by fluctuating alluvial ground water levels (gwl).

Although in situ development is observable to some degree in most riparian soils, it is most apparent in soils above the floodwater level. These soils are often contiguous to upland positions or may occur where vertical accretion has built up surface elevations above normal flood stage. The rate of in situ pedogenesis is greatly affected by soil moisture status.

The OM content of riparian soils varies from near 100 percent in deep organic deposits to less than 1 percent in recent fluvial deposits. The distribution of mineralized OM with depth in soil profiles is often irregular, in contrast to the regular decrease with depth common in soils of upland positions. The distribution of OM within the soil profile is indicative of the rate of fluvial deposition relative to OM production.

Organic matter decomposition is a biologically induced process greatly affected by soil-water content. Decomposition proceeds at a slow rate under anaerobic conditions, more rapidly under wet aerobic conditions, and most rapidly under fluctuating soil moisture status. The degree of OM decomposition in surface and subsurface horizons reflects consistency in soil moisture content.

Flocculation is the aggregation of soil-sized particles (sand, silt, and clay) into peds, the fundamental unit of soil structure. Soil materials incorporating relatively high proportions of mineralized OM and approximately equal proportions of sand, silt, and clay (loamy textural classes) are most affected by flocculation. The degree of ped formation in riparian soils generally increases toward mesic positions characterized by frequent wetting/drying cycles. The elemental composition of cations concentrated near the surfaces of mineral and organic components also affects the degree of ped formation.

The presence or absence of gaseous or dissolved oxygen in soil systems also affects the rate of oxidation/reduction reactions and biologically induced nutrient cycling. The taxonomic classification of riparian soil is based, in part, upon the presence or absence of spots of contrasting colors (mottles) resulting from the segregation of iron and magnesium from soil mineral components. Mottles of high chroma (bright colors) indicate alternating oxidation-reduction processes, while mottles of low chroma (gray colors) are indicative of prolonged reducing conditions.

Some fine-textured subsurface horizons permanently saturated with ground water are of low chroma throughout the matrix and are of blue to green hue (gleyed horizons). These horizons are indicative of permanent anaerobic conditions. Gleyed soil materials often change color when exposed to the atmosphere for even short periods.

Eluviation of mineral, organic materials, or both from surface horizons and illuviation of transported materials in subtending layers are responses to percolation of water through the soil profile. The expression of eluviation and illuviation may be thin films of transported OM or clay-size particles on the walls of soil pores and ped faces in subsurface horizons. The degree of temporal stability necessary for expression of eluviation and illuviation is not common in riparian ecosystems although it may be noted in positions bordering uplands.

The dissolution and precipitation of soluble minerals may be in response to downward percolation of surface water or upward inundation by ground water. Calcium carbonate (lime) and calcium-magnesium carbonate (dolomite) are slightly soluble constituents of many soils. In contrast with upland positions, the concentration of carbonates in riparian positions often decreases with depth in the soil profile as a result of dissolution by alluvial ground water. The characteristic distribution is sometimes accentuated by eolean deposition of fine-grained carbonate sediments from contiguous uplands.

Descriptions of soil genesis and morphology typical in headwater, V-canyon, and broad-valley positions in the Northern Rocky Mountain Physiographic Province were formulated based on interpretations of principal processes affecting distinct positions of riparian ecosystems. The broad range of environmental gradients typical in natural systems results in an infinite degree of variation in morphological characteristics. The following descriptions illustrate the effect of prominent forms of soil genesis but do not include all situations that could be encountered in field investigations.

Glaciated Headwater Positions—These positions constitute the initial convergence of drainage sources for many montane streams. Drainage sources in headwater positions include the melt from snowfields that may endure through most of the warm season, the leakage of bedrock aquifers from extensive exposures of water-bearing geologic strata, or the point discharges of springs. The characteristic dispersed flow and near-saturated surface conditions in headwater positions are conducive to the proliferation of OM. Near-anaerobic conditions in subsurface strata may limit the degree of OM decomposition and mineralization. The morphologies of soils typical on seepy slopes and bogs in headwater positions are depicted in figure 12.

The most apparent process affecting both seepy slopes and bogs in headwater positions is OM proliferation. Surface layers on seepy slopes (fig. 12a) are often relatively undecomposed (fibric) OM in the form of bryophytes and interwoven matting of fibrous roots of herbaceous (generally *Carex* spp.) plants. The undecomposed state of OM in surface horizons may be the result of prodigious annual production and a relatively short season for biological degradation rather than the anaerobic conditions normally associated with fibric OM. Surface horizons are normally wet through most or all of the growing season but saturated for only short periods. Subtending OM is often moderately (histic) to completely (sapric) decomposed and is saturated by flowing water through most or all of the growing season. The flowing water is generally aerated to a degree conducive to biologically mitigated decomposition of OM. The thickness of organic horizons on seepy slopes varies as a complex function of factors affecting biological production and decomposition, and may extend to depths greater than 40 inches. Where organic epipedons are relatively thin, mineral horizons darkened by mineralized OM may subtend organic layers. Subtending mineral material is generally gleyed, indicating prolonged anaerobic conditions. Basal mineral material may be glacial till, glaciofluvial deposits, colluvium, or residuum underlain by weathered bedrock.

Surface horizons of bog soils (fig. 12b) are often relatively undecomposed (fibric) OM. The sum thickness of organic layers ranges from a few inches to greater than 6.6 inches. Thin layers of mineral sediments reflecting sedimentation from contiguous upland positions are often stratified in organic layers. OM is generally subtended by fine-grained, gleyed, mineral material with slow to very slow permeability.

Although the ground water level (gwl) may be well below the organic surface through much of the growing season, the wicking action (capillary rise) through OM often results in near-saturated conditions at the surface throughout much of the biologically active season. In bogs, the vertical accretion of OM acts to extend the vertical (and consequently the horizontal) limits of capillary rise above the gwl. Thus, the proliferation of OM effectively expands the limits of near-saturated conditions.

The accretion of OM in broadly concave positions results in lateral encroachment of near-saturated conditions upon nearby uplands. The presence of decadent conifers surrounded by boggy communities is indicative of OM accretion. Large logs—often preserved so that the species of origin is recognizable, buried deep within saturated OM in central positions of bogs—give further testimony supporting the process of OM accretion. As evidenced by standing-dead conifers within some bog communities, temporal changes in the surface elevations of bog systems may be rapid.

Riparian ecosystems in headwater positions function to reduce sediment transport and to regulate flow to lower drainage positions. Surface organic horizons on both seepy slopes and bogs effectively filter sediments delivered from upland positions. The dispersed, slow flow of water through bogs effectively regulates discharge rates to down-drainage positions.

The morphology of soils in headwater positions is indicative of primary succession in response to inundation by flowing (seepy slopes) or slowly circulating (bogs) drainage water. These ecosystems seem relatively stable under consistent hydrologic regime.

The hydrologic regime of headwater positions may be altered through drainage or by affecting the hydrologic source responsible for sustenance of the riparian ecosystems. Drainage may be a response to head-cutting by streams in lower V-canyon positions, chan-

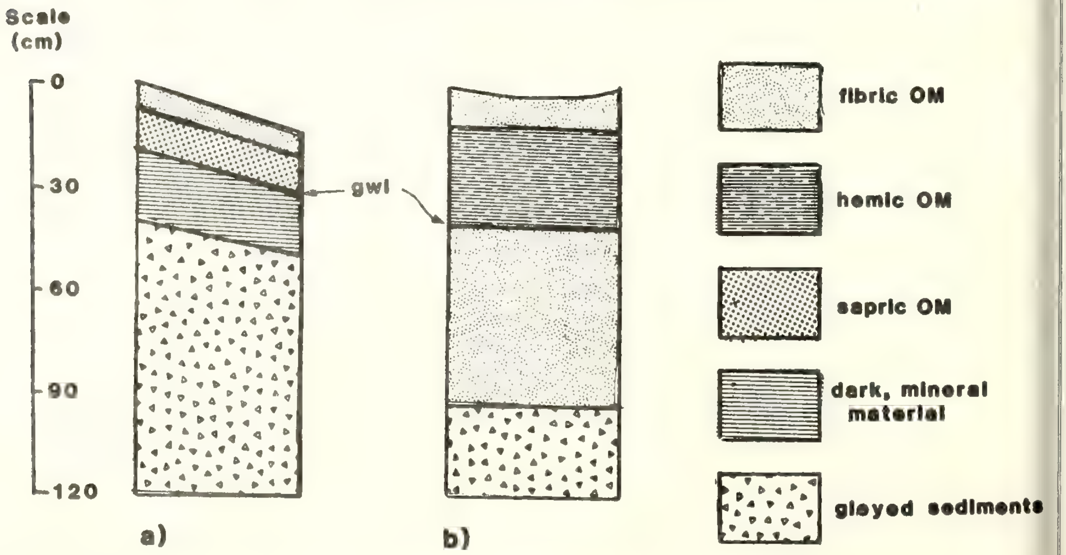


Figure 12—Soil morphology typical in headwater positions: (a) seepy slope, (b) bog soil.

neling resulting from trampling by livestock, or direct manipulating in construction activity. Hydrologic source characteristics may vary in response to short-term or long-term changes in climate or in response to manipulations associated with resource use management. Increased rates of runoff and sedimentation from uplands as a response to logging, mining, grazing, or construction activities may also affect the integrity of headwater ecosystems.

V-canyon Positions—Narrow, V-canyon positions occur predominantly along low-order tributaries of drainage systems. V-canyon positions are associated with steep gradient streams, often with banks rising abruptly to upland positions. The principal processes apparent in V-canyon positions are fluvial erosion and alluvial/colluvial deposition.

Erosional processes proceed toward down-cutting through subtending, consolidated geologic material and head-cutting toward drainage sources. Colluvial sedimentation is in response to the fluvial down-cutting. Typical soil profiles contiguous to stream channels in V-canyon positions are depicted in figure 13.

The morphology of soil in relatively level bank positions (fig. 13a) reflects erosion/sedimentation associated with high-velocity stream flow. In these positions, layers of sand are sometimes found stratified between layers of decaying leaves. Subtending materials are principally unstratified rounded gravel, cobble, stones, and boulders. The composition of these positions is generally a result of lateral accretion acting to redistribute colluvial sediments and sediments eroded from upstream, V-canyon positions. High streamflow velocities and seasonal catastrophic flooding are conducive to the transport of finer grained sediments.

In contrast, soils on steep-banked sites (fig. 13b) are a result of alluvial/colluvial deposition from contiguous valley slopes. The surface is often covered with litter. A thick surface horizon somewhat darkened by mineralized OM and with granular structure is sometimes present. Subtending material includes angular rock fragments eroded from contiguous valley slopes. Occasional surface horizons buried beneath thick strata of colluvial sediments are indicative of mass wasting.

Although close to stream channels, these soils are among the driest. Surface strata are often excessively drained with low water storage capacity. The combination of relatively deep gwl's and coarse-textured material (low capillary rise) generally limits riparian vegetation to deep-rooted, shrubby species (*Alnus, Cornus*, and *Betula* spp.). Herbaceous riparian vegetation is often absent on these positions.

The apparent natural function of V-canyon positions is the fluvial transport of sediments. Fluvial erosion and transport are maintained at a steady state by interrelationships between channel slope and discharge. The effect of human-caused disturbance in narrow V-canyons may be insignificant relative to that of natural catastrophic flooding. In contrast,

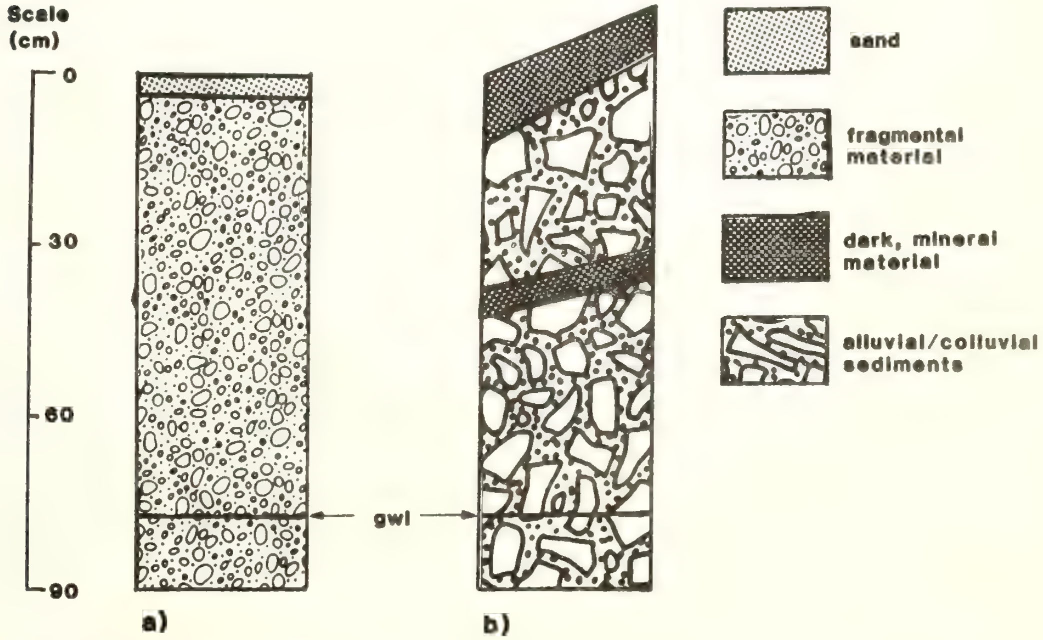


Figure 13—General morphologies of soils common in V-canyon riparian positions: (a) relatively level bank position; (b) steep bank position.

alteration of stream discharge through retention or diversion of upstream sources may affect erosion and transport mechanisms responsible for maintenance of riparian ecosystems in V-canyons. The probable responses to reduction in discharge are increased fluvial sedimentation and accumulation of alluvial/colluvial sediments from contiguous uplands.

Broad-Valley Positions—Soils in broad-valley positions include a greater range in morphological characteristics than do soils in headwater and V-canyon positions. The broad range in characteristics results from spatial variability in valley-bottom geomorphology and its influence upon processes affecting soil genesis. The general form and relative position of stream bars, levees, low-lying wetlands, and meadows are illustrated in figure 14.

Mineral sediments in broad-valley positions may be categorized as one of three basic forms: alluvial sediments from associated uplands, fluvial sediments, or valley fill.

Alluvial sediments from adjacent uplands are generally characterized by relatively fine-grained materials reflective of advanced levels of in situ pedogenesis. Alluvial fans and aprons originating in ephemeral upland washes are examples. Surface horizons in lateral positions of valley bottoms often comprise alluvial sediments.

Fluvial sediments are characterized by a matrix of soil-sized material (sand, silt, and clay), often including rounded rock fragments. Fluvial sediments overlie fragmental valley fill across the valley bottom in all terrestrial positions except stream bars. Depth to the gwl in broad-valley systems generally corresponds with the thickness of this finer grained material over valley fill. Primary factors affecting pedogenesis in broad-valley systems are the thickness and texture of fluvial or alluvial sediments.

Valley fill is characterized by a matrix of rounded gravel and cobble (rubble), normally with sandy material filling interstitial voids. The level of valley fill approximately corresponds with stream base-flow elevation. The relatively high permeability of valley fill promotes equilibration of alluvial ground water and streamflow levels. The often diffuse transition between valley fill and fluvial sediments corresponds with the transition between soil and "not-soil" (USDA-SCS 1975). Following are discussions of distinct landform positions common in broad-valley systems.

Stream bars. Stream bars are considered as both the initial state from which soil genesis proceeds and the limit to which it regresses. The obvious process dominating the genesis and resultant morphology of stream bar soils is fluvial erosion and sedimentation. The extent of stream bars is influenced by the geometry of active stream channels and temporal variability in stream stage level. Shallow, wide streams with substantial differences between normal flood stage and base flow logically are associated with expansive stream bars. Deep, relatively narrow streams with consistent stage levels are not normally associated with stream bars in undisturbed systems. The progressive development of stream bars is illustrated in figure 15.

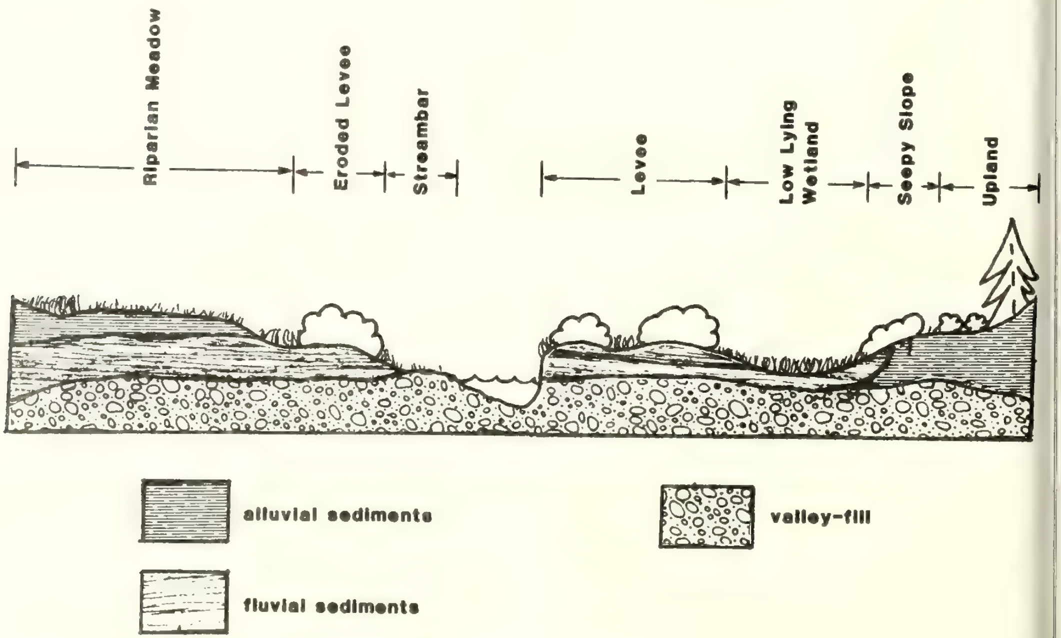


Figure 14—Schematic of geomorphic types in broad-valley systems.

The primal state of stream bars (fig. 15a) is a severely eroded position comprised of fragmental valley fill material and with little or no indication of pedogenic development. The gwl is normally near the mineral surface. However, vegetation may be dominated by mesic species due to low water storage and negligible rise of capillary water above gwl characteristic of fragmental materials.

Given a change from erosional to depositional processes (fig. 15b), sandy fluvial materials may be deposited. The somewhat greater water storage capacity of these sandy materials promotes establishment of more vigorous vegetation, which decreases the potential of subsequent erosion. More vigorous vegetation also results in the accumulation of mineralized OM in thin surface horizons. As seasonal deposition continues, the surface is built up above the normal flood stage (fig. 15c). The presence of buried horizons, darkened by mineralized OM, indicates seasonal deposition of mineral sediments interspersed by periods of relative stability.

Assuming that the natural flux of sediments through broad-valley systems approaches a state of dynamic equilibrium (sediment influx is approximately equal to sediment outflux), the area of stream bars is expected to remain approximately constant in undisturbed systems. As new stream bars are formed by the lateral displacement of stream channels, sedimentation on remnant stream bars results in development toward more stable riparian forms. An increase in the number or extent of stream bars is a primary indicator of disturbance in broad-valley systems.

An increase in the area of stream bars may be a response to degradation of streambanks or decreased streamflow through established channels. The degradation of streambanks and channel geometry may be a direct response to livestock grazing, construction, recreation, or all three. Accelerated rates of streambank sloughing are most often attributed to cattle grazing and result in a change in channel geometry toward broader, shallower streams. Expansive stream bars are often associated with stream crossings frequented by livestock or recreational vehicles. A decrease in discharge resulting from retention or diversion of streamflow may result in diminishing stream area and subsequent increase in the surface area of low-lying stream bars. The effect is most dramatic where channels are broad and shallow.

Channel levees—Levees are normally contiguous to stream channels or stream bars, but may occur throughout broad-valley systems due to displacement of stream channels across the valley bottom. The form of levees is convex and surfaces are generally higher than immediately adjacent positions toward valley edges. Microtopography is often hummocky or undulating, with shrubs (generally *Salix* spp.) dominating on convex positions and herbaceous vegetation in concave channels between hummocks. The lateral migration of stream

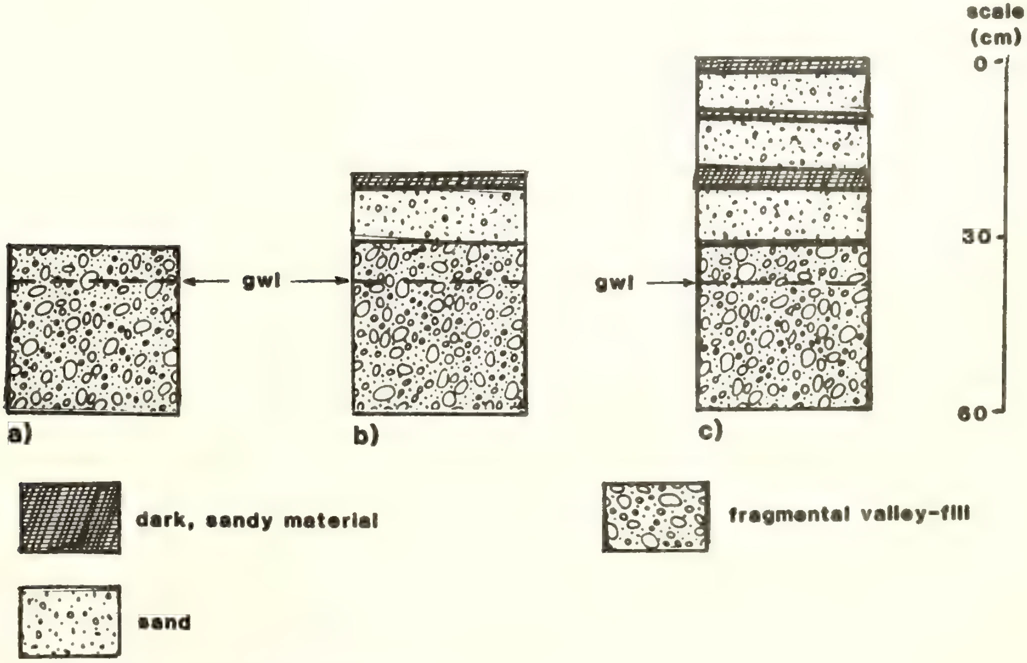


Figure 15—Progressive development of stream bar soils.

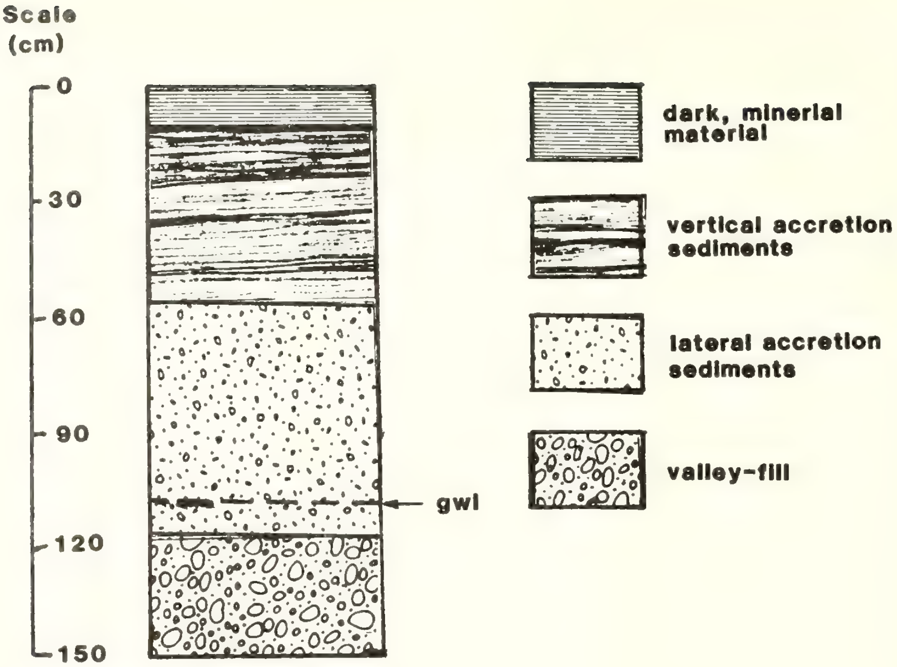


Figure 16—Soil morphology for a typical channel levee.

channels may result in expansive areas of remnant channel levees characterized by undulating or hummocky topography. Processes affecting the genesis and morphology of these soils include sedimentation and processes of in situ pedogenesis. The soil morphology typical of levee positions is depicted in figure 16.

Surfaces are often covered with a thin layer of litter from the previous year's vegetation. Surface mineral horizons are generally darkened by mineralized OM. Subtending horizons may indicate a single episode of vertical accretion, repeated episodes of lateral accretion, or a combination of both modes of deposition.

The apparent function of channel levees is to regulate the rate at which water is distributed across the flood plain during active flood stage. As stream levels rise, channels between convex hummocks fill and may result in dispersed routing of floodwaters to lateral positions of the valley bottom. Channels between hummocks also function to convey runoff from uplands to stream channels. Channel levees act to maintain the integrity of stream channels.

A reduction in vegetative cover may affect both the form and stability of levees. Intensive grazing by livestock, wildlife, or both results in broadening of channels and accentuation of hummocks. Reduction in shrub cover along streambanks may promote streambank sloughing and the formation of stream bars. Dense willow stands associated with stream levees are a favorite source of building materials for beavers.

Low-lying wetlands—These include divorced ox-bows, beaver ponds, channels, and backwaters and may occur anywhere in broad-valley systems. Alluvial ground water constitutes the primary hydrologic source for sustenance of these systems. The genesis of low-lying wetlands may be in response to inundation of drier sites through alteration of the geometry of alluvial aquifers or through the eutrophication of aquatic systems. The activity of beavers may result in localized alteration in the geometries of streams and associated alluvial aquifers.

Surface elevations are generally at or near gwl and forms are concave. Eutrophied aquatic positions in broad-valley systems are similar to bogs in headwater positions. As in headwater bogs, OM proliferation is a primary process affecting soil morphology. Sedimentation of fine-grained mineral materials is generally also apparent. Soil morphology common in low-lying wetlands of broad-valley systems is depicted in figure 17.

Soils of low-lying wetlands that were formed in response to inundation by alluvial ground water (fig. 17a) are typically composed of mineral soil materials or organic materials and are confined to thin surface horizons. What may be apparent is the influence of vertical accretion, lateral accretion, forms of in situ pedogenesis remnant of previous hydrologic

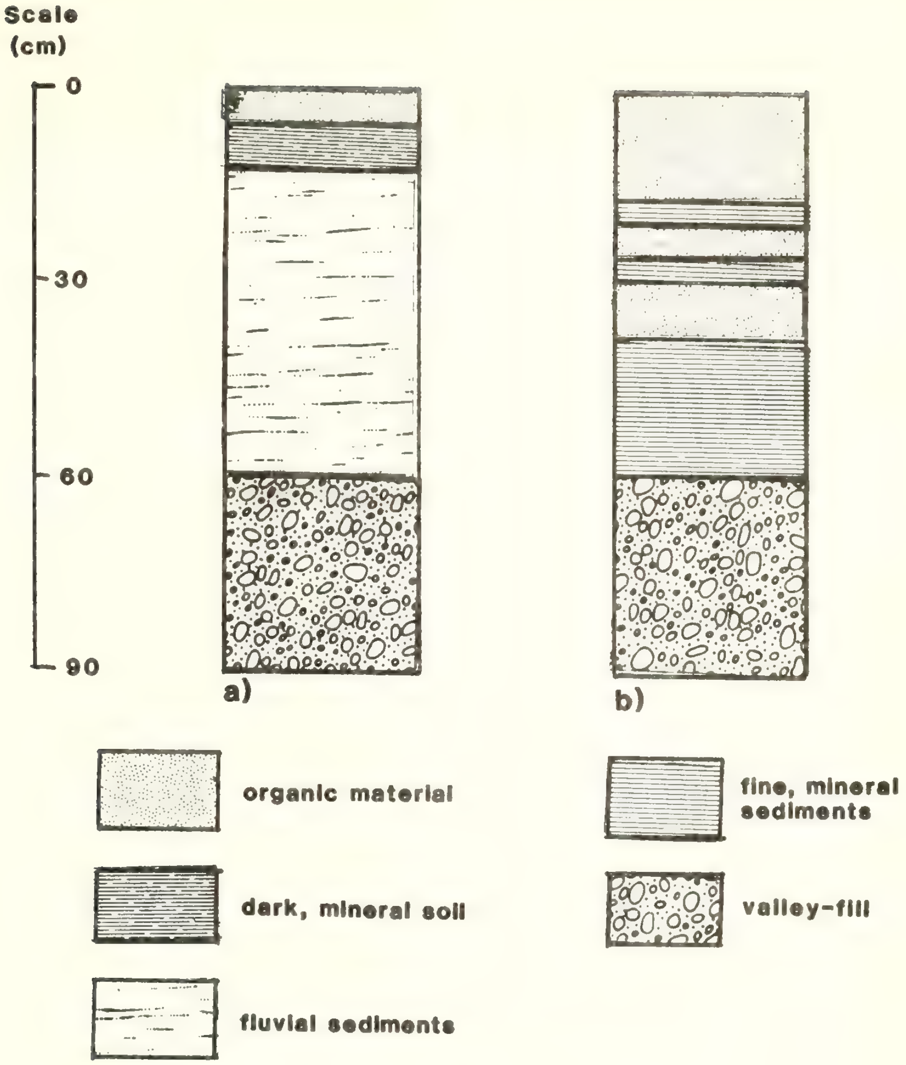


Figure 17—Soil morphology common in inundated low lying wetlands: (a) inundated position, (b) eutrofied aquatic position.

regimes, or all three. Mottles are common through the depth inundated, although gleyed colors associated with anaerobic conditions are uncommon.

Surface horizons of eutrophied aquatic positions (fig. 17b) are often composed of slightly to moderately decomposed organic material. The thickness and degree of OM decomposition in surface strata are primarily dependent upon the degree of saturation by alluvial ground water. Subtending strata are often alternating layers of fine-grained mineral and organic materials that indicate repeated inundation by low-velocity floodwaters and intervals conducive to OM proliferation. Subtending materials are dominantly fine-grained, often gleyed, mineral sediments. Fragmental valley fill normally underlies low-lying wetlands.

Low-lying wetlands function to regulate the discharge and quality of runoff entering streams. Eutrophied aquatic positions may discharge runoff directly to streams through small rivulets or indirectly through recharge of alluvial aquifers. Both modes of discharge effectively reduce sediment load of runoff entering stream systems. High levels of microbiological activity and organic products normally associated with eutrophied aquatic positions may also function to reduce the flux of organic and mineral nutrients entering stream systems through adsorption, chelation, degradation, and assimilation.

Given continued sedimentation and consequent vertical accretion of ground surfaces, the succession of these soils is toward more mesic conditions.

Seepy slopes within broad valleys are generally similar to those described for headwaters. The occurrence of these types corresponds with relatively consistent discharge areas of springs, seeps, or runoff from contiguous uplands. Seepy slopes occur to a more limited extent in broad valleys than in headwater systems.

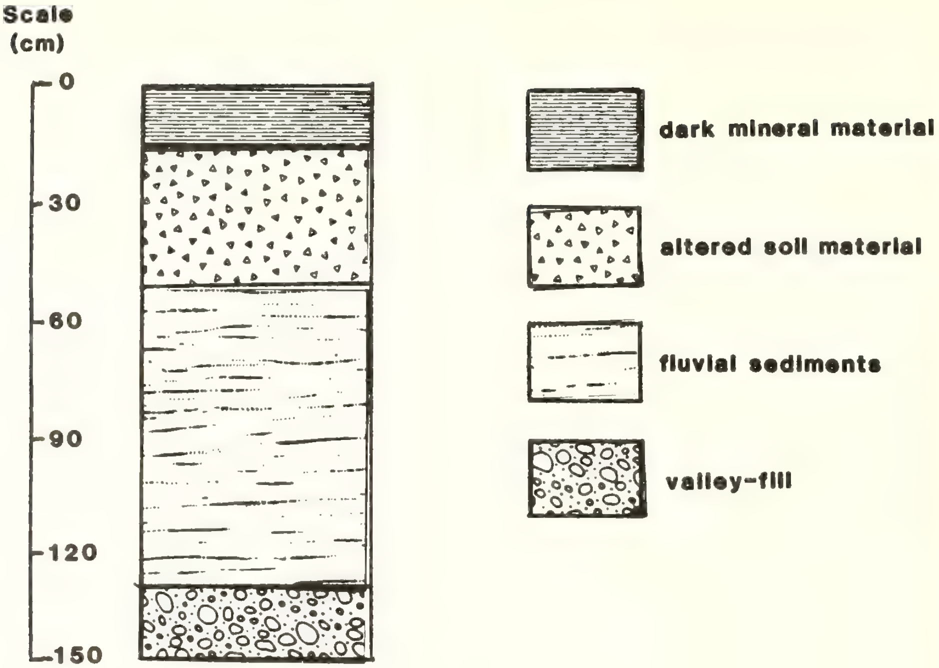


Figure 18—Soil morphology typical of mesic meadow positions.

Riparian meadows—These positions are common where alluviation from contiguous uplands or tributary drainages have affected flood plain geomorphology. Surfaces are generally slightly inclined toward the medial axis of the valley bottom and are smooth. These positions are wet throughout runoff periods but are seldom affected by stream flood waters. Processes apparent in the morphology of soils are those of in situ pedogenesis. The morphology of typical soil in mesic meadow positions is depicted in figure 18.

Morphological characteristics typical of mesic meadow positions are indicative of relatively advanced stages of pedogenic development. Common are relatively thick surface horizons darkened by accumulation of mineralized OM and aggregated into moderate to strong ped structure. The subtending stratum may be enriched by illuvial clay or aggregated into strong ped structure, or both. Undifferentiated alluvial material underlies altered horizons, if present. Alluvial material is generally unaffected by in situ forms of pedogenesis other than oxidation/reduction resulting from annual fluctuations in gwl. Valley fill underlies mesic meadows at a depth generally greater than 3 ft.

Riparian meadows constitute a final stage in progressive pedogenesis of riparian soils. Given continued alluviation from contiguous uplands and subsequent increase in depth to the gwl, these positions may develop soils and vegetation similar to those of uplands. More commonly, riparian meadows may regress to more fundamental riparian forms.

Erosion is the principal process responsible for regression of riparian meadows to more fundamental forms. Where adjacent to streams, the high banks associated with riparian meadows are extremely susceptible to sloughing. Grazing by domestic livestock increases the rate of streambank sloughing.

Soil Taxonomy

Soil taxonomy is a hierarchal system of classification developed by the Soil Conservation Service for making and interpreting soil inventories. A major purpose of the system is to differentiate taxa within a conceptual structure that promotes understanding of functional relationships: those between differing types of soils and those between soils and factors responsible for their character (USDA-SCS 1975). Diagnostic criteria for the classification are physical and environmental properties believed to influence or reflect genetic soil processes. The object of classification is the polypedon, an area of soil that differs in one or more properties from contiguous areas of the landscape to such a degree that the combination of all properties may result in different responses to management. While the polypedon is a tangible entity with distinctive size, composition, and structure, the taxonomy is a conceptual formulation based on apparent soil-forming processes.

Soil taxonomy defines six categories within the classification system. In order of decreasing hierarchal rank and increasing number of differentiae and classes, the categories are:

- order
  - suborder
    - great group
      - subgroup
        - family
          - series

Soil orders are based on morphological evidence of differences in the degree or type of dominant soil-forming processes. The current approximation of soil taxonomy distinguishes 10 soil orders. Names of soil orders may be recognized by the "sol" ending (Entisol, Mollisol, Histisol, and so forth).

The differentiae for suborders vary with the order and include important properties that influence soil genesis and plant growth. Currently, 47 suborders are recognized. Names of suborders have two syllables. The first syllable denotes the suborder differentiae and the second syllable the order.

At the great group taxonomic level, distinguishing criteria consider the collective nature of the soil. Soil moisture and temperature regimes are dominant factors of soil genesis and are properties of the whole soil rather than of specific horizons. About 185 great groups are currently distinguished in the United States. The name of a great group consists of the name of a suborder and a prefix that consists of one or two formative elements suggesting something about the diagnostic properties.

The categories of order, suborder, and great group emphasize evidences of processes that seem to dominate the course or degree of soil genesis. Subgroups designate classes that reflect subordinate processes that further affect the morphology resulting from more dominant processes. These subordinate processes may be dominant in higher categories of the taxonomy but, in a particular soil, only modify the marks of other processes. Three general types of subgroups are identified: (1) the central concept for the great group; (2) intergrades or transitional forms to other orders, suborders, or great groups; and (3) extragrades or soils with some properties that are not representative of the great group and do not indicate transitions to other higher categories.

The names of subgroups consist of the name of the great group modified by one or more adjectives. Subgroups representative of the central concept for the great group are designated as "typic." Intergrade subgroups are named by prefixing the adjective form of the name of the appropriate taxon to the great group name. Similarly, the names of extragrades consist of an adjective denoting the character of the aberrant property attached to the great group name.

Soil families are generally defined by particle-size distribution, mineralogy, temperature regime, and depth. These properties are important factors affecting water-handling characteristics, aeration, and management of soil.

The series is the lowest category of the hierarchal classification. Differentiae used for series are mostly the same as those used for classes in other categories, but the range permitted in one or more properties is less than is permitted in higher categories. Names of soil series are abstract place names generally corresponding to a place near where the series was first recognized. There is little value in applying the series category to classification of wetland soils, primarily due to the lack of defined series for Aquic suborders and subgroups. Although definition of series may be important for future designation of riparian soils, the present state of understanding does not merit the degree of resolution afforded by soil series.

Soil orders most common in riparian positions of the Northern Rocky Mountain Physiographic Province are Entisols, Mollisols, and Histisols. Criteria for the taxa (to the subgroup level) common in riparian positions of the Northern Rocky Mountains are summarized in table 8.

The following discussions of differentiating criteria cover discrete soil orders. Taxa discussed are common in riparian positions associated with low-order streams in mountainous regions of the Intermountain West but are not expected to be consistent in physiographic provinces other than the Northern Rocky Mountains.

Entisols—Entisols are young mineral soils (recent) characterized by the absence of diagnostic horizons indicative of advanced stages of soil genesis. The absence of pedogenic horizons may be a response: (1) to anaerobic environments that restrict chemically and biologically mitigated processes, (2) to inert parent material such as gravel and coarse sand

Table 8—Distinguishing taxonomic criteria to the subgroup level

Classification	Taxonomic Criteria
Order	**Order**
Suborder	**Suborder**
Great Group	**Great Group**
Subgroup	**Subgroup**
Entisols	No pedogenic horizons
Aquents	Saturated to surface
Cryaquents	Cool temperature regime
Typic	None
Fluvents	Deposited by periodic flooding
Cryofluvents	Cool temperature regime
Aquic	Saturated within 50 cm
Mollic	Epipedon of OM accumulation
Typic	None
Orthents	Other Entisols
Cryorthents	Cool temperature regime
Aquic	Saturated within 50 cm
Typic	None
Mollisols	Mollic epipedon (ep)
Aquolls	Saturated to surface at some time
Cryaquolls	Cool temperature regime
Cumulic	Epipedon >40 cm thick
Histic	Histic ep over Mollic ep
Typic	None
Borolls	Cool temperature regime
Cryoborolls	Cool temperature regime
Aquic	Saturated above 1 m
Argic	Illuvial clay accumulation
Argiaquic	Argic and Aquic
Cumulic	ep >40 cm thick (fluvial)
Pachic	ep >40 cm thick (colluvial)
Typic	None
Histisols	Organic soils
Fibrists	Least mineralized OM
Borofibrists	Cool temperature regime
Terric	Includes mineral horizon
Fluvaquentic	Two or more mineral horizons
Typic	None
Hemists	Moderately mineralized OM
Borohemists	Cool temperature regime
Terric	Includes mineral horizon
Fluvaquentic	Two or more mineral horizons
Typic	None
Saprists	Most mineralized OM
Borosaprists	Cool temperature regime
Terric	Includes mineral horizon
Fluvaquentic	Two or more mineral horizons
Typic	None

in stream bar positions, (3) to insufficient time as for recently deposited sediments, or (4) to active erosion proceeding at a rate equal to or greater than that of pedogenic processes. At the suborder level, Entisols are distinguished as Aquents, Fluvents, and Orthents.

Aquents are saturated at or near the soil surface for most of the growing season. The near-anaerobic conditions that characterize Aquents restrict mineralization of organic matter, flocculation of ped structure, eluviation and illuviation, oxidation, and precipitation of soluble minerals. Aquents are usually grey in color (reduced) and may include brightly colored, prominent mottles in surface horizons. Thin strata of relatively undecomposed (fibric) organic material are also common. At the great group level, soils are Cryaquents on the basis of having a cool soil-temperature regime. At the subgroup level, soils identified are mostly Typic Cryaquents. This rather broadly defined subgroup includes wet and cold soils with little evidence of advanced soil development.

Fluvents are Entisols with characteristics other than those of Aquents in which the organic carbon content decreases irregularly with depth. Fluvents include those soils with distinctly segregated horizons characteristic of repeated episodes of fluvial deposition. At the great group level, taxa are Cryofluvents.

Three subgroups of Cryofluvents are common. Aquic Cryofluvents are saturated within 20 inches of the surface for significant periods of most growing seasons. Aquic Cryofluvents are intergrades to Aquents. Mollic Cryofluvents are not saturated within 20 inches of the surface for significant periods and have a surface horizon appreciably darkened by mineralized organic matter. Although the color, structure, and base saturation of the surface horizon are definitive of a mollic epipedon, the thickness of the horizon is less than that required for Mollisols. Mollic Cryofluvents are intergrades to Mollisols. Typic Cryofluvents represent the central concept for the great group.

Orthents are Entisols with characteristics other than those described for other suborders, and they are normally restricted to positions transitional from riparian to uplands. Although sediments comprising Orthents may be alluvial in origin, they normally lack the distinctly stratified layers typical of soils formed by repeated fluvial deposition. At the great group level, taxa are Cryorthents. Subgroups identified are Aquic and Typic Cryorthents. Aquic Cryorthents are saturated within 20 inches of the surface for significant periods of the growing season, while Typic Cryorthents are not saturated and represent the central concept of the great group.

Mollisols—These soils are characterized by a horizon formed at the surface (epipedon) that is appreciably darkened by mineralized organic matter to the extent definitive of a mollic epipedon. Accessory properties of the mollic epipedon include recognizable ped structure and a cation exchange complex dominated by basic cations (Ca, Mg, Na, and K). At the suborder level, taxa common in riparian positions of the Northern Rocky Mountains are Aquolls and Borolls.

Aquolls are wet to the surface for some period of the growing season. Characteristics associated with wetness include distinct and prominent mottles at or near the base of the epipedon, matrix colors of low chroma that indicate a prolonged reducing environment, and ground water present at such a shallow depth that the capillary fringe reaches the soil surface (except in noncapillary pores). Because the genesis of the mollic epipedon requires aerobic conditions favorable to biologically mitigated mineralization of organic matter, the period of time the soil is saturated may be somewhat less than that of Aquents. The concept of Aquolls here includes a fluctuating ground water level, although the taxonomy is not explicit on this point. At the great group level, Aquolls have been identified as Cryaquolls based on soil temperature regime.

Three subgroups of Cryaquolls are common. Those with an overthickened mollic epipedon (greater than 16 inches thick) are Cumulic Cryaquolls. The overthickened epipedon may be the result of long-term organic matter production and concurrent mineralization and redistribution within the soil profile, or by concurrent rates of sedimentation approximately equal to those of organic matter production and mineralization. Histic Cryaquolls have an organic surface horizon overlying the mollic epipedon. Histic Cryaquolls are saturated to the surface for most of the growing season and are intergrades to the Histisol order. Typic Cryaquolls are definitive of the central concept of the great group.

Mollisols described for riparian positions that are not saturated to the surface for significant periods during the growing season are Borolls at the suborder level. Borolls are cool to cold and more or less freely drained. At the great group level, these soils are classified as Cryoborolls, denoting cold temperature regimes with short, cool summers. Genetic influences other than accumulation of mineralized organic material in the surface horizon are often not apparent.

Six subgroups of Cryoborolls have been identified in riparian positions in the Northern Rocky Mountains. Aquic Cryoborolls are saturated within 3 ft of the soil surface for greater than 90 consecutive days. Argic Cryoborolls have a subsurface horizon of illuvial clay accumulation. Argiaquic Cryoborolls have characteristics of both Aquic and Argic subgroups. Cumulic Cryoborolls have an epipedon thicker than 16 inches and an irregular decrease in organic carbon content with depth that indicates fluvial deposition. Pachic Cryoborolls have an epipedon greater than 16 inches thick and a regular decrease in organic carbon content with depth. The Pachic subgroup is common at the base of steep slopes, and the overthickened epipedon is the result of alluvial/colluvial deposition from upslope positions. Finally, the Typic subgroup defines the central concept of the great group.

Histisols—Histisols occur where organic matter proliferation dominates both the mineralization and erosional processes. The order is most commonly associated with seepy slopes and bog positions in glaciated headwaters and low-lying, concave positions in broad valleys. Histisols are uncommon in V-canyons.

Generally, Histisols are soils in which at least half of the upper 32 inches is greater than 50 percent organic material. The cumulative thickness criterion may be modified when organic material rests on rock or fragmental material. Subsequent classes are determined by the degree of organic matter decomposition, soil temperature regime, and presence or absence of mineral horizons. At the suborder level, soils common in riparian positions of the Northern Rocky Mountains are Fibrists, Hemists, and Saprists.

Fibrists are organic soils in which the botanic origin of the dominant organic material is recognizable. These are the least decomposed of organic soils and are generally permanently saturated in fibric horizons. Bryophytes and fibrous roots of monocot species are commonly the source of fibric OM.

Organic soils with intermediately decomposed OM are Hemists. The organic matter is of high fiber content, but the botanic origin of the material is generally not apparent. Hemic horizons are saturated most of the time when temperatures are greater than biologic zero.

Saprists are organic soils in which the dominant OM is almost completely decomposed. The fiber content is low, and the botanic origin is not apparent. A fluctuating soil-moisture regime or flowing ground water, containing sufficient dissolved oxygen for biologic oxidation processes, characterizes sapric horizons.

At the great group level, taxa are Borofibrists, Borohemists, and Borosaprists. The classifications are based on the cool (frigid) soil temperature regime. At the subgroup level, Histisols are Terric, Fluvaquentic, and Typic. Terric taxa have a mineral horizon 12 inches or more thick between 12 and 52 inches deep from the surface. Fluvaquentic subgroups have two or more thin (less than 12 inches thick) mineral horizons within 52 inches of the surface. This taxon is indicative of periodic fluvial deposition interspersed with interludes of organic matter proliferation. Typic subgroups do not have mineral horizons thicker than 2 inches within 52 inches of the surface and are the central concept for the great groups.

Family Differentiae for Mineral Soils—Particle-size class, mineralogy, and soil temperature regime are differentiae for mineral soils at the family level of classification. Particle size refers to the grain-size distribution of the whole soil and is not the same as soil texture, which refers only to particles smaller than 0.08 inch in diameter. The control section for which the particle size is defined normally extends from 10 inches to 3 ft below the surface, although the control section may be defined differently for soils with horizons of illuvial clay accumulation. Strongly contrasting particle-size classes within a single pedon may also be noted in the family classification. Detailed descriptions of particle-size classes, control sections, and criteria for strongly contrasting classes are discussed in chapter 18 of "Soil Taxonomy" (USDA-SCS 1975). Particle-size classes described in the Northern Rocky Mountains range from fragmental (stream bar positions) to fine, although most soils are coarse-loamy and fine-loamy. Particle-size classes are a direct response to the competence of the flowing water responsible for depositing the sediments.

Mineralogy classes are based on the approximate mineralogical composition of selected size fractions of the same control section that is used for defining particle-size classes. Alluvial material constituting flood plains may originate from contiguous uplands or from geological material located well upstream in headwater positions. Alluvial riparian soils are mostly of "mixed" mineralogy class. The class denotes materials with <40 percent of any single mineral type other than quartz or feldspar.

Soil-temperature classes are used as family differentiae unless the name of a higher category taxon carries the same limitation. Because the frigid temperature class is implied in all boric suborders and cryic great groups, repetition of temperature class at the family level is redundant and is thus omitted.

Three examples of family classifications for mineral soils common in riparian positions are:

1. Coarse-loamy, mixed, Typic Cryaquent.
2. Fine-loamy over sandy-skeletal, mixed, Aquic Cryoboroll.
3. Fragmental, mixed Aquic Cryofluvent.

Family Differentiae for Organic Soils—Family differentiae normally applied to organic soils in riparian positions include particle-size, mineralogy, soil temperature, and soil reaction classes. Particle-size modifiers are used only in Terric subgroups of Histisols. The number of particle-size classes used for organic soils is considerably less than for mineral soils, although criteria for the broader classes are identical to those defined for mineral soils. Similarly, application of mineralogy classes is normally restricted to Terric subgroups.

Rules for family designation of soil temperature classes are identical to those for mineral soils.

Reaction classes are used to indicate the pH of undried organic materials. Classes are (1) euic - pH is 4.5 or greater, and (2) dysic - pH is less than 4.5. Examples of family classifications of organic soils are:

1. Loamy, mixed, euic, Terric Borofibrist.
2. Sandy, mixed, euic, Fluvaquentic Borosaprist.
3. Dysic, Typic Borohemist.

Soil Description

Soil descriptions serve as a basis for taxonomic classification and for interpretations as to use and management. A complete explanation of standards and guidelines for conducting soil descriptions is given in chapter 4 of the "Soil Survey Manual" (USDA-SCS 1981). Field descriptions often require considerable qualitative and quantitative judgment on the part of the investigator. Judgments should be calibrated at frequent intervals, especially when investigators have little experience in taxonomic soil description. While field descriptions may be of sufficient detail and accuracy for classification and general interpretation, analytical laboratory tests may be necessary for validation and for specific interpretations. Standard forms for conducting soil descriptions are presented in appendix 3 of this publication.

Summary

Soil genesis is a response to climatic, hydrologic, and biologic processes acting upon geologic material. Geomorphic position, relative to fluvial and alluvial ground water geometries, is a primary factor determining the rate and degree to which processes affect the soil system. A history of processes affecting riparian ecosystems is evident in the morphology of soils.

Biologically mitigated processes often dominate the genesis of soil in glaciated headwater positions. Surface horizons on seepy slopes are generally organic soil material. Bogs in concave headwater positions may be organic soil material to depths greater than 6.6 ft. These positions function to reduce sediment flux to lower drainage positions. Management of headwater positions should be designed to maintain hydrologic sources responsible for sustenance of riparian ecosystems and to limit disturbances that may lead to drainage.

Fluvial erosion and alluvial/colluvial sedimentation are principal processes in V-canyons. Coarse-textured soils containing high volumes of rounded or angular rock fragments characterize fluvial and alluvial/colluvial positions, respectively. A significant reduction in upstream discharge may result in degradation of these systems through relatively fine-grained sedimentation and debris jams.

A dynamic equilibrium between fluvial erosion and sedimentation characterizes undisturbed broad-valley systems. Stream bars, channel levees, low-lying wetlands, and riparian meadows are distributed in response to geomorphic position relative to alluvial and fluvial ground water geometries. Management resulting in disturbance of the equilibrium between erosion and deposition or a change in drainage characteristics may result in alteration of the distribution or the proportional area of distinct riparian types in broad-valley ecosystems, or in both distribution and area.

Riparian areas are open systems that function to regulate the flux of water, sediments, and nutrients between upland and aquatic ecosystems. The genesis of undisturbed riparian ecosystems is toward conformity between form and function. The structure and function of unique riparian types, as expressed in soil morphology, are a response to the same processes that they function to regulate. Interpretations of soil morphology may be useful for developing management alternatives for riparian ecosystems.

REMOTE SENSING

Remote sensing is the collection and analysis of information about lands and resources, using a device not in physical contact with the lands or resources. Remote sensing includes techniques ranging from analysis of satellite, Side Looking Air Borne Radar, and thermal infrared scanning data, to interpretation of aerial photography.

The size and shape of riparian areas can often be determined from satellite digital analysis or interpretation of small-scale airphotos. However, large-scale airphotos at scales ranging from 1:1,000 to 1:4,800 are needed to interpret detailed information on streams and riparian vegetation. The 1:1,000 scale is best for ease of photo interpretation and good resolution, but it is difficult to achieve stereo coverage at 1:1,000 scale due to 9 × 9 film recycling speed and safe, low-level aircraft speed. The compromise scale of 1:2,000 is acceptable and achievable.

Color infrared photographs (CIR) are especially valuable for vegetation analysis. Color tones, along with shape, size, pattern, shadow, texture, and site, are used to identify individual trees and shrubs in riparian areas. Color infrared film can be overexposed by ½ f stop to penetrate clear water in streams and lakes (Cuplin 1978).

Types of riparian vegetative information that can be collected on the ground are vegetative type and subtype; width of riparian area; species composition of shrubs, trees, grasses, and forbs; the amount of bare soil; plant density; condition class; reproduction; trend; structure; and potential.

Interpretation of large-scale air photos combined with ground truthing produces a list of variables that can be readily studied: vegetation type and subtype, width of riparian vegetation zone, riparian area acreage, structure, percent ground cover of trees, shrubs, and herbaceous vegetation, percent bare soil, and density of large shrubs and trees. Stream variables that can be measured from air photos are stream width, stream channel stability, streambank stability, flood plain width, and stream shade.

Subtle changes in riparian vegetation are difficult to detect on air photos. Conversely, catastrophic changes due to flooding can be easily monitored and the amount of riparian area loss readily calculated.

Application of Large-Scale Photos for Inventory and Monitoring

Ground sampling or familiarity with the riparian vegetation photographed is essential for accurate photo interpretation. Vegetation transects and tree-shrub circular plots are transferable in general terms to large-scale photos. Trees and some shrubs can be readily identified by species; grasses and forbs cannot be readily identified by species.

Variables that may or may not be photo-interpreted from 1:2,000 scale color infrared air photos combined with on-the-ground data collection are as follows:

Variable	Photo interpreted or calculated
Vegetation type and subtype	Yes
Riparian area width and acreage	Yes
Plant species composition	
Trees	Yes
Shrubs	Yes, some shrubs such as willow and baccharis
Grasses	No
Forbs	No
Ground cover (in percentage)	
Trees	Yes
Shrubs	Yes
Herbaceous vegetation	Yes
Bare soil	Yes
Density	Yes, large trees, some shrubs such as cottonwood and willow
Reproduction	Yes, young trees and shrubs but not seedlings
Condition class	No
Trend	Yes, as related to change in the amount of ground cover and bare soil
Potential	No
Structure	Yes, height of trees and shrubs
Streambank shade	Yes
Stream width	Yes
Flood plain width	Yes
Streambank stability	Yes
Streambed silt	Yes
Stream channel stability	Yes

Baseline

The original large-scale air photos of a riparian area provide an overview of existing conditions in terms of the readily interpreted variables. Subsequent photos over time provide the means of detecting change. Subtle change due to below- or above-normal precipitation may not be as evident as the catastrophic change caused by a 100-year flood.

The most easily detected subtle change in a riparian area would be a reduction in foliar cover and an increase in bare soil. This change may be obvious upon inspection of the baseline photo compared with the monitoring photo taken 5 to 10 years later. The cause of the change may be answered only by on-the-ground inspection. Thus, the photos offer the opportunity to monitor change but do not provide the cause.

Ground Data Collection

Ground data sites should be accessible and representative of the riparian vegetation and stream conditions. One site per stream may be sufficient for a 1- to 3-mile stream segment for air photo interpretation. If there are significant differences in a stream segment, additional data collection sites should be established.

On-Site Data Collection

The first step in on-site data collection is to take color print 35-mm photographs of the stream riparian area (upstream, across stream, and downstream) at the site where the air photo target is placed. Then a stream inventory should be conducted along one-tenth mile of stream segment. Dominant and subdominant herbaceous vegetation, shrubs, trees, and percent bare soil are then determined. Additional field notes may assist in photo interpretation.

Acquisition of Large-Scale Aerial Photographs

Most photo interpretation can be accomplished with a minimum of equipment. The 9- by 9-inch photos, which are easy to work with, are identified by date, fiducial marks, agency, photo scale, state symbols, roll number, and exposure number. Photos can be easily filed and extra prints ordered as needed for field use. The 9 by 9 format photo covers approximately 52 acres or 1,500 ft^2 at a scale of 1:2,000. At this scale riparian areas on first, second, and third order streams are easily photographed with a good margin of upland vegetation.

Assistance on an air photo acquisition should be sought from a remote sensing coordinator. A Bureau of Land Management publication "Aerial Photography Specifications" (USDI, BLM 1983) is available from the Branch of Remote Sensing, Denver Service Center, Denver, CO. This publication provides detailed specifications for acquiring aerial photographs via contract. The photographer should be provided a U.S. Geological Survey quadrangle map that shows the beginning and end of each stream-riparian area to be photographed. Flight lines on the maps will indicate to the photographer the direction of airplane travel and midpoint and width of each flight line according to the photo scale that is requested.

Although the 9 by 9 format is preferred, there are now procedures that allow acquisition of 35-mm aerial photos for small riparian areas. These procedures would not be suited for large riparian-stream areas unless the photographer is very experienced and the topography conducive to aerial photography. The procedure uses a hand-held 35-mm camera and small bubble-type helicopter to acquire the photographs (Meyer and others 1982). The right door of the helicopter is removed to allow for near-vertical photographs.

Monitoring Procedures and Area Management

Using the large-scale photos and the ground data baseline inventory, the researcher or manager identifies the riparian-stream segment and describes the segment's existing conditions. Resource needs and concerns are then identified.

After identifying the objectives and goals for the area, the manager then needs to determine where improvements can be made and changes can be measured, such as increasing the amount of ground cover, narrowing stream width, or increasing the number of trees and shrubs.

Variables

Variables that can be used to easily detect change are:

1. *Ground cover*—An increase or decrease in ground cover, such as trees, shrubs, and herbaceous vegetation, and in bare soil can be detected by visual observation of large-scale air photos.
2. *Stream width*—This can be easily measured on large-scale air photos and is an early indicator of improving or degrading stream conditions. Stream width increases under heavy livestock grazing and narrows during the recovery period of no livestock grazing.
3. Stream channel and streambank stability.
4. Riparian area width and acreage.

Sample Size

The sample size used to determine change should be large enough to represent the changes that have occurred. A representative site can be identified on both baseline and monitoring air photos.

Results

If results are uncertain, other comparative areas should be analyzed. Managers need to determine if objectives were achieved from the changes detected.

WATER COLUMN MEASUREMENTS

The water column is the medium of support and movement for fish and other aquatic organisms and is strongly controlled by its bordering riparian vegetation. This vegetation reduces water velocity, which in turn reduces the erosion of banks and channels by increasing column and channel roughness. The amount of sunlight, which is the energy base for photosynthesis and stream temperature, is also controlled by the surrounding vegetation.

Vegetative Canopy Closure and Density

The concave spherical densiometer, model B (Lemmon 1956a and b) can be used on permanent points or transects to estimate relative vegetative canopy closure or canopy density caused by vegetation (fig. 19). Vegetative canopy closure is the area of the sky over the selected site (stream channel) bracketed by vegetation. Canopy density is the amount of the sky blocked within the closure by vegetation. Canopy closure can be constant throughout the season if fast-growing vegetation is not dominant, but density can change drastically if canopy vegetation is deciduous.

The concave mirror surface of the densiometer has 37 grid intersections forming 24 squares. At a probability level of 95 percent, tests show that average measurements of the same overstory area can be expected to be within ±2.4 percent of the mean (Lemmon 1956a and b). Because the instrument has a concave reflecting surface resulting in a field that includes lateral as well as overhead positions, an overlap of side readings occurs when readings are taken from the same point. To account for this bias, the modifications developed by Strichler (1959) are used and modified to better measure canopy closure and density. Strichler uses only 17 of the line intersects as recording points by taping a right angle on the mirror surface as shown in figure 19. Closure and density can be recorded on any selected site. Because the canopy over the stream is so important, the stream is used as an example of the densiometer's use.

For Stream Orders 1 Through 4—The densiometer is held in the hand on the transect line perpendicular to the right streambank 12 inches from and 12 inches above the shoreline. A tripod can be used for more accurate measurements. The arm from the hand to the elbow is horizontal to the water surface. Reasons for this position are: (1) it is easier to

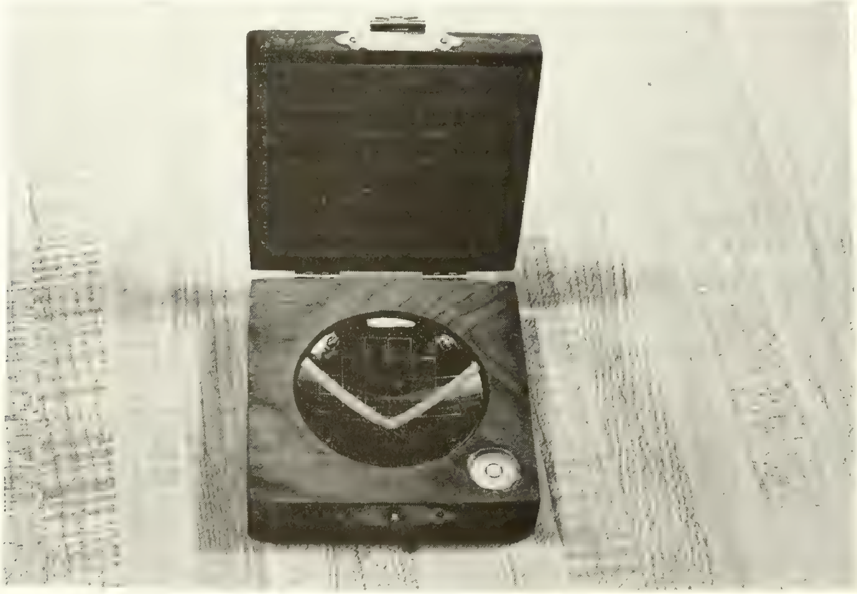


Figure 19—The concave spherical densiometer, model B.

read the densiometer than if it were held directly on the bank; (2) the point of measurement can be repeated; (3) the cone of overhead observation is more directly overhead and takes in only a small area beyond the bank; (4) low overhead canopy overhanging the water column within 12 inches of the water surface has significant fishery cover benefits; and (5) the identical measurement settings eliminate parallax bias.

The densiometer is held away from the observer with the bottom of the V pointed toward the recorder. The observer's head reflection should almost touch the top of the grid line. Room is left to observe all points at the 12 o'clock position at the top grid line (fig. 20). The densiometer must be kept level using the level bubble. The grid between the V formed by the tape encloses 17 points. The number of points (line grid intersects) that are surrounded by vegetation (canopy closure) or are intercepted by vegetation (canopy density) are counted within the V outlined area (maximum of 17). Each horizontal-vertical line intersect (point) has a value of 1.5 percent when four different recordings are made on streams of order 4 or less. On stream order 5 and larger where eight recordings are required, each point has a value of 0.75 percent.

The same procedure used previously on the right bank is used on the transect line in the center of the stream, one recording taken facing upstream and one facing downstream. The densiometer is held level over the transect line 12 inches above the water surface. The last reading is taken at the left shoreline. Readings have then been taken that simulate each of the four cardinal directions.

The points counted for each reading are totaled and multiplied by 1.5 to obtain the percentage canopy closure or canopy density, whichever is desired. The average of all closures or density measurements on all transects on the stream reach being studied are

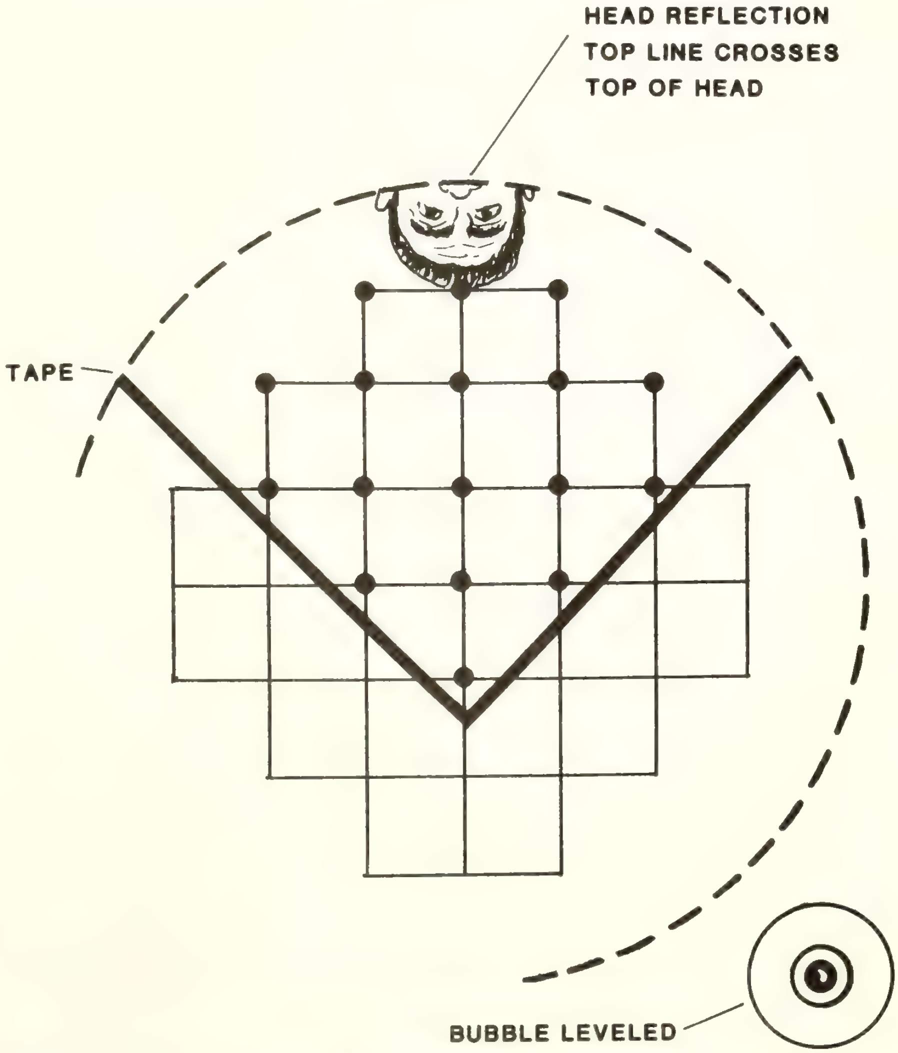


Figure 20—The concave spherical densiometer with placement of head reflection, bubble level, tape, and 17 points of observation.

totaled and averaged to obtain the overall closure or density measurement. Then, 1 percent is deducted from scores between 30 and 65 percent, and 2 percent for those scores over 66 percent. No deduction is made for scores between 0 and 29 percent.

Stream Orders 5-7—The same procedure is used as in stream orders 1 through 4, except that eight recordings are made on these wider streams. This is required so that the two stream shore readings do not overinfluence the midchannel readings. The streambank readings are done the same as for stream orders 1 through 4. Two readings are taken at each quarter, half, and three-quarter interval across the transect. One reading is taken facing upstream and the second one downstream, identical to the readings explained previously for the midpoint of the transect. The eight recordings are totaled and multiplied by 0.75 to obtain percentage closure or density. Then 1 percent is deducted from scores between 30 and 65 percent, and 2 percent for those scores over 66 percent. No deduction is made for scores between 0 and 29 percent.

Light Intensity

Measuring light intensity provides a means of estimating how effective the canopy is at shading the stream. This method is easy to use, requires no instruments, and is often accurate enough for estimating intensity of sunlight under vegetation canopies (Wellner 1979). The method works best under tight canopies that exert little filtering effect on the passage of light, such as coniferous trees. But it can also work under deciduous vegetation during full-leaf conditions. This method works best where the light pattern beneath the canopy is essentially a mosaic of patches of full sunlight and deep shade. If these conditions are not met or if more precise measurements are needed, the solar integrator or canopy density techniques should be used.

Light intensity is evaluated as follows:

Light conditions	**Intensity rating**
Direct sunlight	100
Filtered sunlight	50
Shade	7

Measurements are made visually on randomly selected transects using a white disc 3 inches in diameter. The light intensity is measured at each shore, each quarter point, and at the midpoint of selected transects on small streams of orders 1 through 4. For larger streams, more measurements will be needed to properly represent the transect. At least 100 observations (one observation is one single measurement) are collected from the area studied to account for variation between observations. For year-to-year comparisons, the light readings should start at the same time (say, 1100 hours) and end at the same time (say, 1300 hours) during the same period each year. Light intensity is measured only when the sun is clearly visible, only between the hours of 1100 and 1300, and during the period solar energy is the most influential (usually July and August).

The determination of average light intensity through the study area is made by multiplying the percentage of the total number of observations that were full sun by 100, the percentage of the total that were filtered sunlight by 50, and the percentage of the total shaded measurements by 7, and then dividing the sum by 100.

$$\text{Mean light intensity} = \frac{A(x) + B(y) + C(z)}{100}$$

where:

A = percentage of "full sun" observations
B = percentage of "filtered sunlight" observations
C = percentage of "shaded" observations
x = 100 (full sun)
y = 50 (filtered)
z = 7 (shaded).

For example, suppose that 10 percent of the total observations were direct sun, 25 percent were filtered sun (partial shade), and 65 percent were completely shaded. Mean light intensity would then be:

$$\text{Mean light intensity} = \frac{(10)(100) + (25)(50) + (65)(7)}{100}$$

$$\text{Mean light intensity} = \frac{2{,}705}{100}$$

$$= 27.05 \text{ or } 27 \text{ percent of full sunlight}$$

Wellner (1979) used a similar method (identical except Wellner did not use a filtered category) in coniferous forested canopies for comparison with the Shirley radiometer on 18 sample plots. The results showed no difference greater than 6 percent of full sunlight; 15 were less than 3 percent different and six were less than 1 percent different. For most field studies, this method will therefore produce fairly reliable results.

Stream Surface Shading From Surrounding Vegetation

Interception of the sun's rays by riparian vegetation strongly influences stream temperatures. Techniques are therefore needed to determine or predict the heat the stream receives and the effects that existing or potential riparian vegetation would have on solar heat transfer.

Quigley (1981) has developed a deterministic model that represents a theoretical approach to the estimation of stream surface shade during the most critical periods of the year. His approach can be applied to any specific stream reach for any given hour, day, month, or year, to determine the percentage of the water column being shaded. For management purposes, it is usually only necessary to determine heat input and output during critical periods. The computer program in appendix 6 makes this complicated analysis simple and fast, but the procedure that follows can also easily be performed in the field with a hand-held calculator.

Stream surface shade varies with stream, vegetation, and shading characteristics. The determination and description of each characteristic are necessary before stream surface shade can be estimated. Overstory vegetation, mountains, cliffs, undercut banks, and logs or brush lying across streams must be considered in determining the amount of shade. This technique covers only the influence of overstory vegetation. The other shading components can be accounted for by using the solar integrator technique discussed later.

Stream Characteristics—Average stream width (W) and the average distance of the shading vegetation to the stream shore (Y) need to be determined (see table 9 for variable definitions). The stream orientation angle (R) is determined from U.S. Geological Survey quadrangle maps using the directions from figure 21. Characteristics can vary between streambanks. Therefore, each bank should be treated separately if this difference is large or if one streambank creates most of the shade because of stream orientation (east-to-west-flowing streams may have the south bank contributing all the shading).

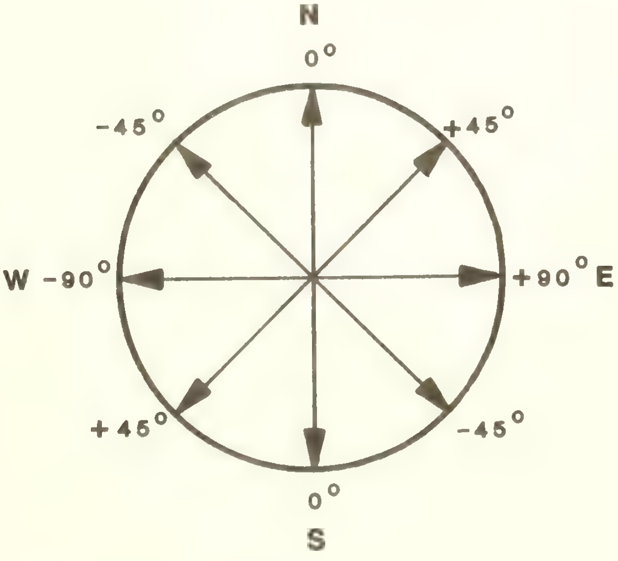


Figure 21—Stream orientation in degrees.

Table 9—Definitions of variable measurements

Stream Characteristics

1. Stream width (W) = the average wetted width of the stream surface through the stream reach evaluated.
2. Vegetation to stream distance (Y) = the average distance from the base of the vegetation to the stream's edge.
3. Stream orientation (R) = the degrees the stream deviates from a north to south orientation. If the orientation is toward the east, it is positive; toward the west, it is negative. The range is between 0 (north to south) to 90° (east to west). Some streams are oriented such that the sun may rise and set on the same side of the stream during part or even all of the year. For example, an east-to-west flowing stream bordered by high vegetation could be shaded during the entire winter.

Vegetation Characteristics

4. Overstory (vegetation) height (T) = the average maximum existing or proposed height of the streamside shading vegetation in the reach being analyzed.
5. Vegetation density (D) = the average screening of incoming sunlight by the shading vegetation. Density accounts for both the continuity of vegetation along the streambank and the filtering effect of leaves and stands of vegetation along the stream. For example, if only 50 percent of one side of the stream has vegetation and this vegetation actually screens only 50 percent of the sunlight, then the vegetation density for this side is only 0.25.
6. Crown measurement (C) accounts for vegetation overhang. It is the average of the maximum diameter of the vegetation immediately adjacent to the stream. The crown measurement for hardwoods is the crown diameter; for softwoods it is the crown radius to account for their tapered form.
7. Vegetation offset is the average distance of the vegetation stems or trunks from the water's edge. Together with crown measurement, the net overhang vegetation is determined

Shadow Characteristics

8. Shadow length = a function of the height of vegetation and the angle of the sun's rays (T (tan Z)).
9. Zenith angle (Z) = the angle of the sun's rays when measured from the vertical and varies according to time of year (declination of the sun, d), time of day (hour angle, h), and latitude (L) according to the relationship:

   $\cos(Z)$ zenith angle $= \sin(L)\sin(d) + \cos(L)\cos(d)\cos(h)$
10. Declination of the sun (d) = the angle of the sun's rays hitting the surface of the earth. The time of year directly predicts the angle of the sun above or below the equator. The angle increases in the Northern Hemisphere from December 21 to June 21 and decreases from June 21 through December 21.
11. Hour angle (h) = the angle of the sun as related to longitude. The sunrise/sunset hour angle is a measure of time expressed as an angle, between solar noon and sunrise/sunset. At noon, local standard time, the sun is directly overhead (0°). Hour angle gets progressively larger (positive) from noon as the sun moves toward evening. At sunrise it has its largest daylight negative angle, and the angle progressively approaches 0 as the sun approaches solar noon. Solar noon is when the sun is at its zenith.
12. Latitude (L) = the angular distance north and south of the equator measured in degrees or a measure of the angle between horizontal surfaces along the same longitude at the equator and at the site. Latitude is readily obtained from many sources, such as U.S. Geological Survey quadrangle maps. Latitude is used by the in-stream water temperature model with the time of year to track the sun.
13. Azimuth angle (A) = the orientation of the shadow from south. This angle is a function of time of year, time of day, and the zenith angle. At solar noon, the azimuth angle is zero; between sunrise and solar noon, it is negative; and between solar noon and sunset, it is positive. Therefore, all streams that reach azimuth angles are between $-90°$ and $+90°$. If the stream meanders greatly, then the analysis can be separated into multiple steps (subreaches) and the results combined for a weighted stream-reach shade average. The stream azimuth is important to orient the shadows with respect to the water surface. The east side of the stream is always on the left side because the azimuth is always measured looking south for streams located in the north latitudes. Note that an east-west oriented stream dictates the east or left side by whether the azimuth is a $-90°$ (left-hand is the north side) or $+90°$ (left-hand is the south side).
14. Altitude angle = the vertical angle from a level line at the streambank to the general top of the local terrain when looking 90° from the general stream-reach azimuth. There are two altitude angles—one on the left and one on the right side of the stream. The altitude is 0 for level plain topography and greater than 0 for hilly or canyon terrain. The altitudes for opposite sides of the stream are usually different. The solar shade model allows for separate altitudes for both sides of the stream. This angle can be obtained easily either from field measurements or from spot-check calculations using U.S. Geological Survey topographic maps and is used to determine local sunrise and sunset times.

Vegetative Characteristics—The average height of the overstory vegetation (*T*) causing the shading, the vegetative density (*D*), and the crown width (*C*) of the shading vegetation must be determined. Vegetative density is measured using the same methods discussed earlier under canopy closure and density measurements. The crown width is the crown diameter for brush and hardwoods, and the crown radius for conifers. The crown measurement accounts for that area of the overhead vegetative canopy that creates shade in the stream direction.

Shadow Characteristics—Shadow length (fig. 22) is determined from the height of the vegetation causing the shade and the angle of the sun's rays intercepted by this vertical vegetation, called the zenith angle (*Z*). Shadow length is equal to the vegetative height multiplied by the tangent of the zenith angle—*T*(tan *Z*). The tangent, sine, and cosine functions can easily be obtained with a scientific hand-held calculator.

The zenith angle varies according to the time of year depending on the declination of the sun, *d* (table 10), the time of day depending on hour angle, *h* (table 11), and the increasing angle as the sun's apparent location is shifted either direction from solar noon.

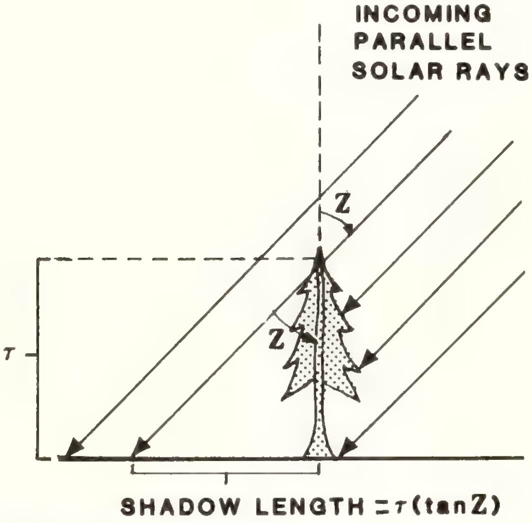


Figure 22—Zenith angle (Z) and shadow length.

Table 10—Approximate solar declination, *d*, for various dates (Quigley 1981)

Date	*d*(°)	Date	*d*(°)
Mar. 1	−8	July 1	23
Mar. 21	0 (vernal equinox)	July 15	21
Apr. 1	4	Aug. 1	18
Apr. 15	9	Aug. 15	14
May 1	15	Sept. 1	9
May 15	19	Sept. 21	0 (autumnal equinox)
June 1	22	Oct. 1	−3
June 21	23 (summer solstice)	Oct. 15	−8

Table 11—Hour angle (*h*) for 0800-1700 local standard time (Quigley 1981)

Local standard time	*h*(°)	Local standard time	*h*(°)
0800	−60	1300	15
0900	−45	1400	30
1000	−30	1500	45
1100	−15	1600	60
1200	0	1700	75

Stream Surface Shade Model—The percentage of the stream surface that is shaded when vegetation is continuous is determined by:

$$\text{Percent of stream surface shaded} = \left(\frac{100}{\text{mean stream width}}\right) \times \left[\begin{pmatrix}\text{Shadow}\\ \text{length}\end{pmatrix} \times \begin{pmatrix}\text{Angle of}\\ \text{shadow}\end{pmatrix} - \begin{pmatrix}\text{Distance from shore}\\ \text{that shadow begins}\end{pmatrix}\right]$$

and to account for the density of the streamside vegetation:

Percent of actual
stream surface shaded

$$= \frac{(\text{Vegetative density}) \times (\text{Percent stream surface shaded})}{100}$$

and in alphanumeric functions:

$$P = \left(\frac{100}{W}\right) \times \left[T\,(\tan Z)\,(\sin A - R)\right] - \left(Y - \frac{C}{2}\right)$$

$$S\ (\text{by day, hour, period, etc.}) = \frac{D \times P}{100}$$

where:

P = percent shaded
W = average stream width
T = average overstory height
Z = zenith angle
A = azimuth angle
R = stream orientation
Y = vegetation to stream distance
C = crown radius or diameter.
D = canopy density.

Applying the Shade Model—The percentage of the stream shaded over a given stream section can be estimated at any time or period of time for any specific dates (table 12). For example, shade cover to protect stream temperatures may be most needed during the thermally critical periods of July and August, between the hours of 1100 and 1600. By determining the percentage of the stream being shaded each hour within this period, summing, and dividing by the number of separate determinations (in this case, 5), the mean stream surface shade (S) can be determined for the period (table 12). Further, the percentage of stream surface shaded can be determined for selected dates throughout the year to determine the most critical shading periods. The procedures are explained more thoroughly in the following example.

Given:

1. Average stream width (W) = 25 ft (use either meters or feet, but be consistent throughout the calculations).
2. Average streamside vegetative density (D) = 40 percent.
3. Average overstory vegetative height (T) = 30 ft.
4. Average vegetation to stream distance (Y) = 5 ft.
5. Hardwoods crown diameter (C) = 20 ft.
6. Average stream orientation (30° west of south) (R) = 30°.
7. Latitude (L) = 42°N.
8. Sun declination on August 1 (d) = 18°.
9. Date of analysis is August 1 at 1000 hours, h = 30°.

Procedures:

Step 1 - Determine zenith angle. It is easier to obtain this angle from prepared table 12; if tables are not available, calculate as follows:

$$\begin{aligned}\text{Cos (zenith angle)} &= (\text{sin latitude})(\text{sin solar declination})\\ &\quad + (\text{cos latitude})(\text{cos solar declination})\\ &\quad + (\text{cos hour angle})\end{aligned}$$

Table 12—Zenith and azimuth angles and percent stream shade for the example stream at lat. 42° N. on August 1 (Quigley 1981)

Hour	Hour angle (°)	Zenith (°)	Azimuth (°)	Stream shade (pct)
1000	−30	35	−56	40
1100	−15	27	33	30
1200	0	24	0	19
1300	15	27	33	9
1400	30	35	56	23
1500	45	45	72	40
1600	60	56	84	40
Mean				29

$$Z = (\sin 42°)(\sin 18°) + (\cos 42°)(\cos 18°) + (\cos -30°).$$

$$Z = 35° \text{ for 1000 hours.}$$

Repeat by determining Z for each hour angle for 1100 to 1600.

Step 2 - Determine azimuth angle. It is easier to obtain these angles from prepared tables, but they can be calculated as follows:

$$\text{Sin (azimuth angle)} = \sin A$$

$$= \frac{(\text{cos declination}) \times (\text{sin hour angle})}{\text{sin Zenith angle}}$$

$$\text{Sin } A = \frac{(\cos 18°) \times (\sin -30°)}{\sin 35°}$$

Azimuth angle = −56° for August 1 at 1000 hours.

Repeat for each hour between 1100 to 1600.

Step 3 - For August 1 at 1000 hours:

$$\text{Percent shaded area } (P) = \left(\frac{100}{W}\right) \times \left[T\,(\tan Z)\,(\sin A - R) \right] - \left(Y - \frac{C}{2}\right)$$

$$P = \left(\frac{100}{25}\right) \times \left[30(\tan 35°)(\sin -56° - +30°) \right] - \left(5 - \frac{20}{2}\right)$$

$$P = 100$$

then

$$\text{Actual stream surface shaded } S_{(1000)} = \frac{D \times P}{100}$$

$$S_{(1000)} = \frac{(0.40)(100)}{100}$$

$$S_{(1000)} = 40 \text{ percent}$$

Do the same for each hour from 1100 to 1600. The amount of the stream surface shaded = S = 29 percent.

Stream Surface Shading From Topographic and Vegetative Features

An in-stream water temperature model that predicts stream temperatures by computer analysis and that is more accurate than the ones discussed previously has been developed by Theurer and others (in 1984). The computer model can predict average daily and diurnal temperature fluctuations throughout a drainage system. The model differentiates stream shading from both topographic and vegetative features and relates this to effects on stream temperature. The overall model evaluates solar radiation as a function of latitude, time of year, basin topographical characteristics, and prevailing meteorological conditions. The solar shade factor portion of the model is a part of the computer program in appendix 6.

The solar shade factor is a combination of topographic and riparian vegetative shading as modified from Quigley (1981). Topographic and riparian vegetative shading is distinguished for each side of the stream. The analysis is modified to include the intensity of the solar radiation throughout the entire day.

Topographic shade dominates the shading effects because it determines the local time of sunrise and sunset at the site. Riparian vegetation is important for shading between sunrise and sunset only if it casts a shadow on the water surface. Topographic shade is a function of (1) time of year, (2) stream reach latitude, (3) general stream reach azimuth, and (4) topographic altitude angle. (See fig. 23.) The riparian vegetative shade is a function of (1) height of vegetation, (2) crown measurement, (3) vegetation offset, and (4) vegetation density. (See table 9 for definitions.) The model allows for conditions on each side of the stream to be evaluated separately and combines topographic and riparian shade to get total shade.

The Model—The solar shade model is calculated in two steps. First the topographic shade is determined according to the local sunrise and sunset times for the specified time of year. Then the vegetative shade is calculated between the local sunrise and sunset times. The vegetative factors consist of four basic vegetative values: crown measurement, height, offset, and density.

The model determines level-plain and local sunrise and sunset times, which then allow topographic shade to be computed. The model then keeps track of time and the amount of shadow cast throughout sunlight time for the sun side(s) of the stream; this allows vegetative shading to be determined. The two combined constitute the total shading. The model determines the actual solar radiation intercepted by all obstacles and expresses shade factors as a ratio of the intercepted amount to the total amount.

Model Solution—The program was developed for the HP-41C desk-top portable computer and appears in appendix 6. The shade program allows the user to specify up to 12 time periods and the physical, topographic, and vegetative shade factors for up to three reaches at a time. Independent physical shade factors are expected for each side of the stream. Of course, if there is no essential difference between sides, the same factors may be used for each side.

For each requested period and reach, the solar shade program predicts the time averaged: (1) local combined sunrise/sunset altitude, (2) topographic shade factor, (3) riparian shade factor, and (4) total shade factor.

The five necessary stream geometry input data for each reach are latitude, stream azimuth, average stream width, topographic altitude angle, and riparian vegetation.

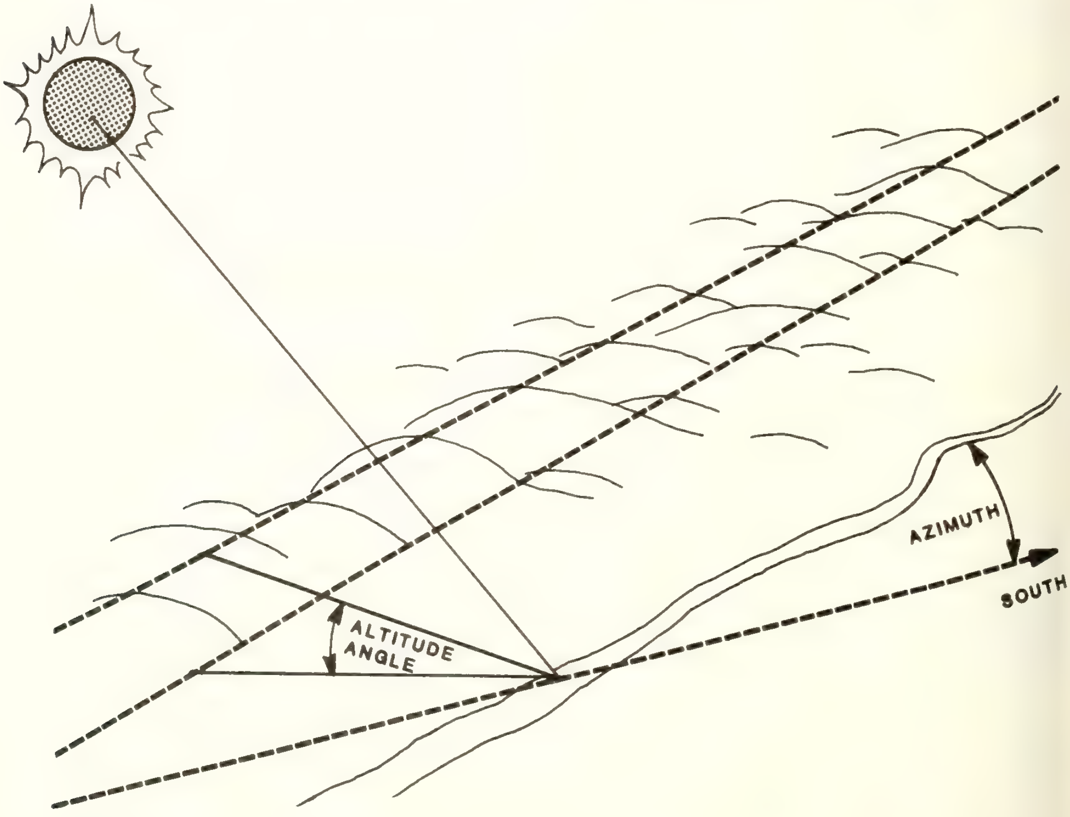


Figure 23—Local solar and stream orientation angular measurements (from Theurer and others 1984).

The observer has control over the selection of time periods. The user can select predefined periods by months or can define a period that better meets the needs of the study. The user can select which single month or group of months (month loop) but must also specify what daily increment is to be used. Obviously, 1-day increments are the most precise but are not always warranted. If the user selects the daily period option, then only one period grouping can be used at a time, but the daily increment is still selected.

The observer can also select whether to use an annual distribution of vegetative density or select the actual density directly for each reach for a given period. If the annual distribution option is selected, the user must provide the yearly minimum and maximum values for each reach and stream side. The model calculates the actual value as a function of the Julian day. The minimum is assumed in the winter, the maximum in the summer. Leaf-out in the spring and leaf fall in the summer are also assumed. If the density for each selected reach is chosen, then no variation in time is assumed for that particular run.

The solar shade program is interactive and prompts for all input. The variable name list in table 13 defines each input output variable involved. During the input sequence, numbers appear as a part of the variable name. They pertain to the reach identification number. East and west bank designations are referenced according to the stream azimuth, looking south regardless of the direction of the flow. Therefore, the left side is always the east bank and the right side is the west bank. This is still true for a due-east orientation (azimuth of −90°); the left or north side, by convention, is designated the east bank.

The procedure to use the solar shade program is:

1. Clear the HP-41C
2. Execute "SIZE 101"
3. Load the solar shade program
4. Execute "ASN **S O L S H A D** Σ+"
5. Execute "SOLSHAD"
6. Repeat step 5 as needed.

Model Run Example—A stream reach is located at lat. 42°30′ N. and is oriented from true northeast to southwest at 30°20′ azimuth. The valley is mountainous with a topographic altitude—analogous to Quigley (1981) zenith angle—of 25° on both sides. The above measurements were obtained from U.S. Geological Survey quadrangle maps and have been confirmed in the field. The field trip determined that the west side was farmed leaving no riparian vegetation, but the east side was heavily forested with large evergreen trees along the stream. The average crown measure was 19.7 ft, stream width was 32.8 ft, the offset vegetative distance was 4.9 ft, the average tree height was 19.7 ft, and the left bank had only 20 percent open spaces. Because the trees were several stands deep from the bank, 100 percent of the sunlight was filtered. Because the riparian vegetation consisted of evergreens that were several stands deep from the bank, the vegetative density was assumed to be a constant 0.80.

Table 13—The variable name list in typical sequential order

Input

LAT = latitude, degrees·minutes
AR = stream reach azimuth, degrees·minutes
B = average stream width, meters
aTE = east side topographic altitude, degrees·minutes
VCE = east side crown measurement, meters
VHE = east side height, meters
VOE = east side offset, meters
VDE = east side density, decimal
aTW = west side topographic altitude, degrees·minutes
VCW = west side crown measurement, meters
VHW = west side height, meters
VOW = west side offset, meters
VDW = west side density, decimal

Output (time period averages)

aS = local combines sunrise/sunset altitude, degrees·minutes
ST = topographic shade factor, decimal
SV = riparian vegetation shade factor, decimal
SH = total shade factor, decimal

Table 14—Program output from the shade model example

Month		Sunrise/set altitude (deg.min)	Shade factor (decimal)		
Name	No.		Topo.	Veg.	Total
May	5	21.31	0.0911	0.2950	0.3862
June	6	20.53	.0838	.2719	.3557
July	7	21.14	.0872	.2838	.3711
Aug.	8	21.55	.1019	.3151	.4170
Sept.	9	21.29	.1281	.3430	.4711

The fisheries specialist is interested in water temperatures because steelhead trout (*Salmo gairdneri*), spring chinook (*Oncorhynchus tshawytscha*), and fall chinook spawn in the stream. The specialist also needs information from May through September and is willing to use monthly time periods with 2-day increments. The HP-41C printer displays the input sequence and the corresponding output. The output is summarized in table 14. While the output varies from May to September, there is not a large variation between successive months. Therefore, the 2-day increment was valid and probably could have been increased to 3 or even 4 days to reduce computation time.

Solar Heat Inputs Using the Solar Pathfinder™

Direct solar radiation, reflected radiation from the channel and water, atmospheric temperature, and riparian reflection are the major sources of heat absorbed by water. Of these, the most important to streams, and the one most under our control, is the proportion of solar radiation intercepted by vegetation as modified by local topographic features.

Evaluating the effects of stream surface shading by vegetation or topographic features requires tracking the shadows cast throughout the solar energy receiving period. Only shadows that intercept the water surface are of immediate interest. The procedure used must account for the obstacle intercepting the sunlight and the length of the shadow this obstacle casts over the water. The two methods discussed previously will determine the contribution of overstory vegetation to stream surface shade, but they are time consuming and can involve some laborious mathematical solutions. Another, simpler approach is to use the Solar Pathfinder™. Part of this section is taken from "The Solar Pathfinder™—The Energy Evaluator," a manual from Solar Pathways, Inc., 7800 Highway 82, P.O. Box 914, Glenwood Springs, CO.

The Solar Pathfinder takes a theoretical approach to integrating all of the effects of azimuth, topographic altitude, height of vegetation, sunrise/sunset angle, latitude, time of year, and hour angle, to determine the influences of solar radiation (see Solar Pathways, Inc. 1983). The Solar Pathfinder allows all the vegetation and topography contributing shade to be permanently recorded at any time and displayed immediately. One recording documents the solar radiation input into the stream over the entire year, by month, half-hour intervals, or any other timeframe of interest. A record of all obstacles providing shade is obtained and can be compared with future readings to evaluate shading changes over time.

Description—The Solar Pathfinder consists of a transparent dome that reflects a clear panoramic view of the area around the site. This allows the shading objects to be identified and mapped. A built-in compass and bubble level permit orientation of the instrument. A pivoting base on a tripod allows the instrument to be used at heights that best fit the user. Worksheets are provided to facilitate a quick estimate of the absolute energy available to enter the stream surface using known radiation values. Monthly sunrise and sunset times, sunrise and sunset directions, interim shading patterns, and the energy-loss consequences of each shadow cast can then be determined.

Operation—The image of surrounding obstacles is viewed by looking directly down into the dome of the instrument (fig. 24). The sun need not be shining to use the instrument; if it is the operator may stand at any position around the dome using his or her shadow to cover the dome so as not to stare at the sun's reflected image on the dome surface. Staring at the sun's image can be harmful to the eyes and should be avoided. If the observer's shadow falls across the area to be measured, this area can be profiled by changing the observer's position and, if needed, shading the sun spot area with the hand. Only that area of the dome in the site panorama that coincides with the measurement area on the Sunpath Diagram™ is needed for analysis.

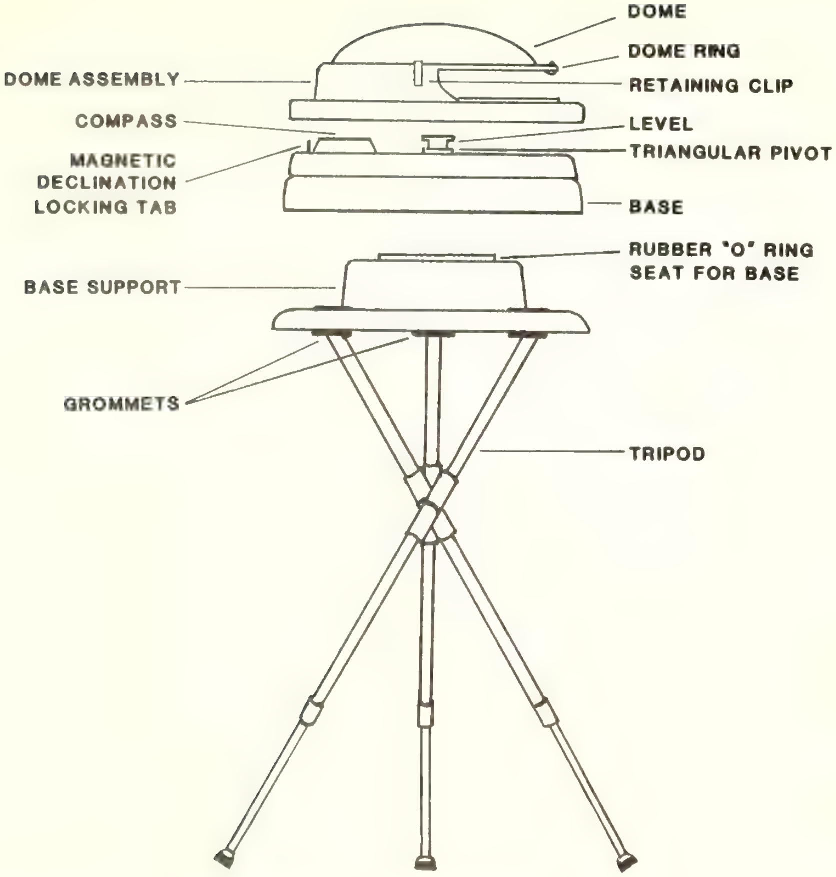

DOME
DOME RING
DOME ASSEMBLY
RETAINING CLIP
COMPASS
LEVEL
MAGNETIC DECLINATION LOCKING TAB
TRIANGULAR PIVOT
BASE
RUBBER 'O' RING SEAT FOR BASE
BASE SUPPORT
GROMMETS
TRIPOD

Figure 24—A schematic drawing of the Solar Pathfinder™ with parts identified.

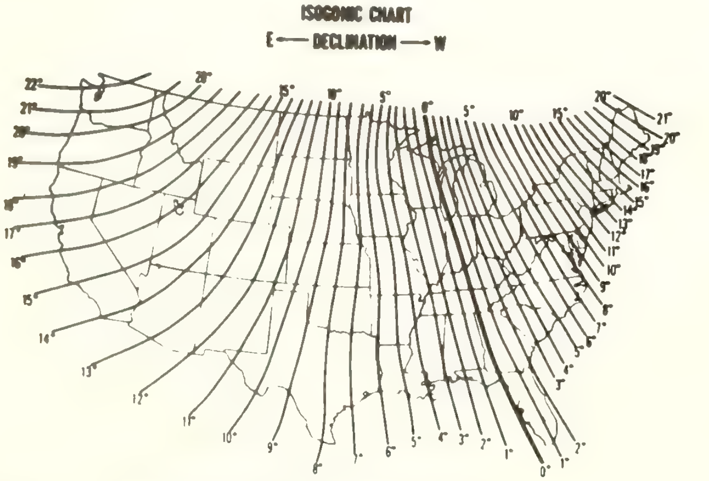

ISOGONIC CHART
E ← DECLINATION → W
22°
21°
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
3°
2°
1°
0°
1°
2°
20°
15°
10°
5°
0°
5°
10°
15°
20°
21°
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
3°

Figure 25—Isogonic chart for the conterminous United States.

The Solar Pathfinder diagrams have been prepared to correspond to the latitude requirements of the selected study areas. Therefore, the proper diagram must be used.

A monthly Horizontal Sunpath Diagram is inserted on the operating face. The instrument must be referenced to true south, in contrast to magnetic south. This is accomplished using a built-in declination adjustment. This setting is subject to accidental change and should be checked frequently. The adjustment (declination) between true and magnetic south can be determined from figure 25. The Solar Pathfinder has a bubble level within the base support. Once level, the south-seeking compass needle is pointed directly at the south reference point.

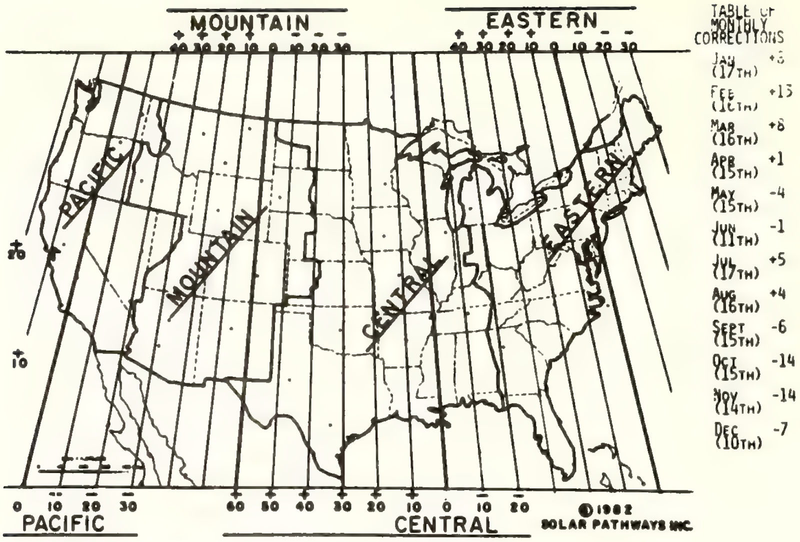


Figure 26—Corrections needed in minutes to correct solar time to standard time. Standard time is equal to solar time plus or minus the two corrections (monthly and longitudinal).

The Sunpath Diagram allows the recorder to plot the solar interceptor profile that is used to obtain percentage solar availability for an average day, hour, or half-hour during any given month. Viewing from between 12 and 18 inches above the dome, and within 10 to 15 degrees of the vertical centerline, provides acceptable accuracy. Shading obstacles are mapped through coincident sighting of the reflected image from the outer surface of the dome with the image on the diagram card. Clouds are not considered an obstruction.

The monthly Horizontal Sunpath Diagram contains a sunpath arc for each of the 12 months and a solar time grid. To change solar time to standard time, two corrections are needed, one for time of year, and one for minutes of time from the Standard Meridian for a given time zone (fig. 26). For example, in San Francisco in November, solar time from the Pathfinder is 3:20 p.m. and the monthly correction (from the right hand edge of fig. 26) is −14 minutes, while the longitudinal correction (from map portion of the same figure) is +10 minutes. Therefore, Pacific standard time is really 3:16 p.m., a difference of 4 minutes. One hour is subtracted to convert to daylight savings time.

Data Collection and Calculation—The boundary between the unobstructed sky and all intercepting objects that appear on the horizon is traced in white grease pencil on the diagram. To avoid breaking the white lead, a light tracing is made under the dome and darkened later after removing the diagram from the dome.

The average percentage of monthly total radiation that will fall on the selected area is taken directly from the diagram (the small white numbers on the monthly curves). The solar radiation received at the site is estimated by adding the unshaded (unobstructed sky) half-hour numbers across the arc of the selected month or group of months or by subtracting these shaded numbers from 100 percent (fig. 27).

In the example in figure 27, during the month of July the numbers in the obstructed, or "under horizon" portion, are equal to 8. One hundred minus 8 means 92 percent of the potential solar radiation was reaching the site if canopy density was 100 percent. Using table 15 for Boise, ID, in July, the average British thermal units (Btu's) of heat per square foot per day available to the water (a horizontal surface) are 2,611. Then 2,611 × 92% = 2,402, so 2,402 Btu's were available to each square foot of surface water on the average each day in July. The Btu conversion table takes into account relative humidity and sunshine-cloud ratio. These tables are available for areas throughout the United States.

Interpretation—Streams, because of turbulence, usually experience mixing of waters from top to bottom. Thus, water temperatures are considered uniform throughout any given cross-section at any given instant for most streams. But canopy density can change with the seasons (such as leaf drop), canopy closure can change with land-use activities (such as logging and grazing), and the average afternoon air temperature is greater than the daily air temperature. Such potential modifying factors must be taken into consideration in the interpretation of the data collected. In addition, different streams are suscep-

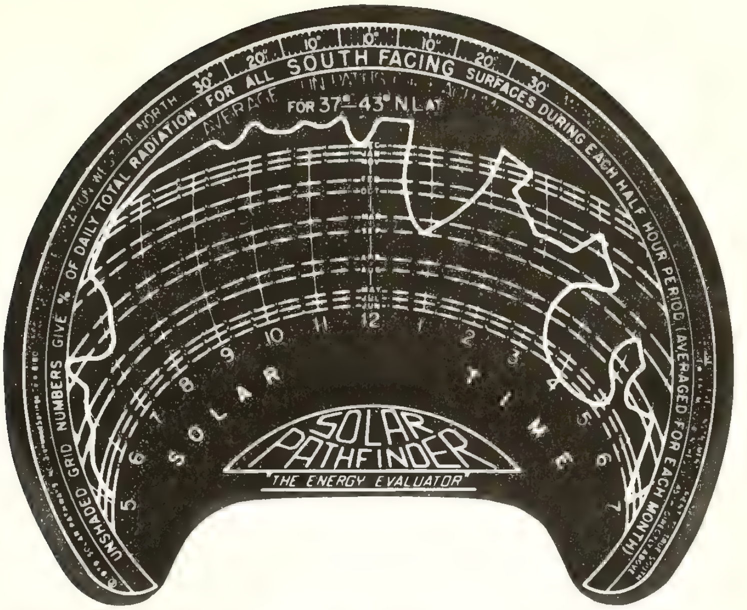

10° 0° 10° 20° 30°
SOUTH FACING
FOR ALL
SURFACES DURING EACH HALF HOUR PERIOD (AVERAGED FOR EACH MONTH)
UNSHADED GRID NUMBERS GIVE % OF DAILY TOTAL RADIATION
FOR 37°-43° N LAT
5 6 7 8 9 10 11 12 1 2 3 4 5 6 7
SOLAR TIME
SOLAR PATHFINDER
THE ENERGY EVALUATOR

Figure 27—An example of the border between the sky and vegetation and topography interceptor areas as related to the monthly sun-path arcs.

Table 15—Some examples of energy values hitting horizontal surfaces by month by selected sites (Btu/ft²/day)

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Boise, ID (Lat. 43.6)	485	839	1,303	1,825	2,275	2,461	2,611	2,195	1,736	1,137	628	437
Cedar City, UT (Lat. 37.7)	881	1,179	1,634	2,091	2,466	2,704	2,502	2,240	1,967	1,459	992	785
Elko, NV (Lat. 40.8)	689	1,034	1,462	1,899	2,302	2,532	2,622	2,314	1,892	1,322	812	616
Missoula, MT (Lat. 46.9)	312	574	981	1,382	1,781	1,932	2,326	1,880	1,357	812	409	267
Pocatello, ID (Lat. 42.9)	539	881	1,370	1,819	2,279	2,478	2,598	2,238	1,768	1,202	689	476
Pullman, WA (Lat. 46.7)	454	671	1,095	1,681	1,998	2,529	2,603	2,035	1,578	944	542	354
Reno, NV (Lat. 39.5)	800	1,149	1,648	2,158	2,521	2,700	2,690	2,404	1,996	1,430	911	705
Rock Springs, WY (Lat. 41.6)	734	1,088	1,530	1,943	2,343	2,573	2,546	2,238	1,832	2,186	826	650
Salt Lake City, UT (Lat. 40.8)	638	988	1,453	1,893	2,361	2,559	2,588	2,253	1,842	1,293	787	570
Spokane, WA (Lat. 47.7)	314	606	1,040	1,494	1,917	2,082	2,356	1,941	1,434	840	397	255

tible to different limiting factors at different times. Some streams may lose fish biomass because they are too cold in the winter (anchor ice and ice flows), while other streams may lose fish biomass because they heat too much during the critical parts of the summer. Therefore, timing can play an important role. The Solar Pathfinder allows you to stratify or select those specific periods in which the data are needed to make a temporal or instantaneous analysis of the effects of solar radiation or even an estimate of the riparian canopy available to produce organic energy (such as leaf fall) to the stream.

Topographic shade dominates the amount of shade a stream receives because it determines the time of sunrise and sunset with respect to the stream surface. We usually have little control over topographic features. The riparian vegetation is usually the most important shading feature between sunrise and sunset that we have some control over.

Evaluating Critical Periods—To evaluate the effect of riparian vegetation on intercepting solar or reflected radiation during critical periods, the sun's path must be determined. The path must then be related to the interception of the sun's rays by surrounding riparian vegetation to determine the effects of any proposed use or treatment. For instance, if logging were proposed in a riparian area, the location and amount of solar energy-intercepting-vegetation proposed for removal needs to be determined so that changes in the amount of solar radiation reaching the stream can be evaluated to determine tradeoffs on a before-the-fact basis. This means that the topographic-vegetative boundary image drawn on the Solar Pathfinder diagram must be refined to include the typing of the solar energy interceptor (obstacle). Thus, the types and the effectiveness of the solar blocking obstacle can be identified.

The topographic-vegetative profile plotted in figure 28 is further stratified into its solar interceptor types, and each interceptor type rated as to its ability to intercept all of the solar rays. Topographic features (streambanks, mountains, and so forth) usually have a density of 100 percent with respect to sunlight penetration. The riparian vegetative density is obtained from canopy density measurements described previously.

In figure 28 for the January sunpath arc, in which back-reflected radiation may be more important than direct solar radiation, the direct average solar radiation reaching the stream surface is (2 + 4 + 5 + 6 + 7 + 8 + 8 + 9 + 9 + [8 × 0.1] + [8 × 0.1] + [7 × 0.1] + 6) = 78.3 percent. At Boise, ID, in January, there are 485 Btu's being received per square foot per average day. So each square foot at the site would receive an average of 380 Btu's per square foot per day. A more detailed analysis (not appropriate here) would be needed to determine whether the incoming radiation under a canopy of this type is more important in the winter than the back-reflection of heat (especially during nighttime conditions or under a much denser canopy where the stream surface would only be receiving 10 percent of the available solar energy).

In July, the direct average solar radiation reaching the stream would be 93.2 percent. If this stream were susceptible to temperature problems, little relief would be obtained from existing riparian vegetation. Measures may therefore need to be implemented to increase the amount and height of the streamside vegetation.

A more refined analysis of the vegetation can be made in certain situations, such as logging, to better determine which trees or groups of trees are being eliminated from the riparian habitat and what effects on solar radiation their removal might have. Furthermore, the user may want to identify the gaps in riparian vegetation along the selected sun arc to determine what method would best fill these gaps. While this may be done directly from the diagram cards, it may help the evaluation considerably to also evaluate these gaps directly in the field. This can be done by using a clinometer in conjunction with the Solar Pathfinder angle estimator diagram (fig. 29). This grid gives a direct reading for azimuth (degrees east or west of true south) and altitude or the elevation above the point on the horizon you are considering. The radial lines measure azimuth and the concentric lines measure altitude. Both are recorded in degrees.

Because each hour of time passes through 15 degrees of azimuth, it is easy to write the time of day (solar time) directly on the diagram. For example, 0 degrees or straight south would be 12:00 noon. At 15 degrees east it would be 11:00 a.m., and so on. The same approach is used to record the time by azimuth as the sun moves west of 12:00 noon. Thus, for any given time, the horizontal direction of the sun is quickly determined from the Solar Pathfinder angle diagram.

The true position of the sun at any given time can be determined by merely plugging in the altitude of the sun for any selected day, at any selected latitude, for any given time from tables found in meteorological books in local libraries. A fairly accurate approximation can quickly be obtained (for the monthly average only) by overlaying a reversed negative (so the black portion of the diagram becomes transparent and you can see through it) of the Pathfinder Sunpath Diagram.

Using the first method of getting the altitude from the tables, the user only has to line up the clinometer with the correct azimuth angle and shoot the correct altitude angle (see table 16). That point selected by the clinometer is where the sun would be on that certain time and day. This allows the user to plot the path of the sun during the critical period. For instance the pathway could be visually plotted on August 1 between the hours of 10:00 a.m. and 2:00 p.m. when 48 percent of the total daily radiation would be hitting the surface of the water.

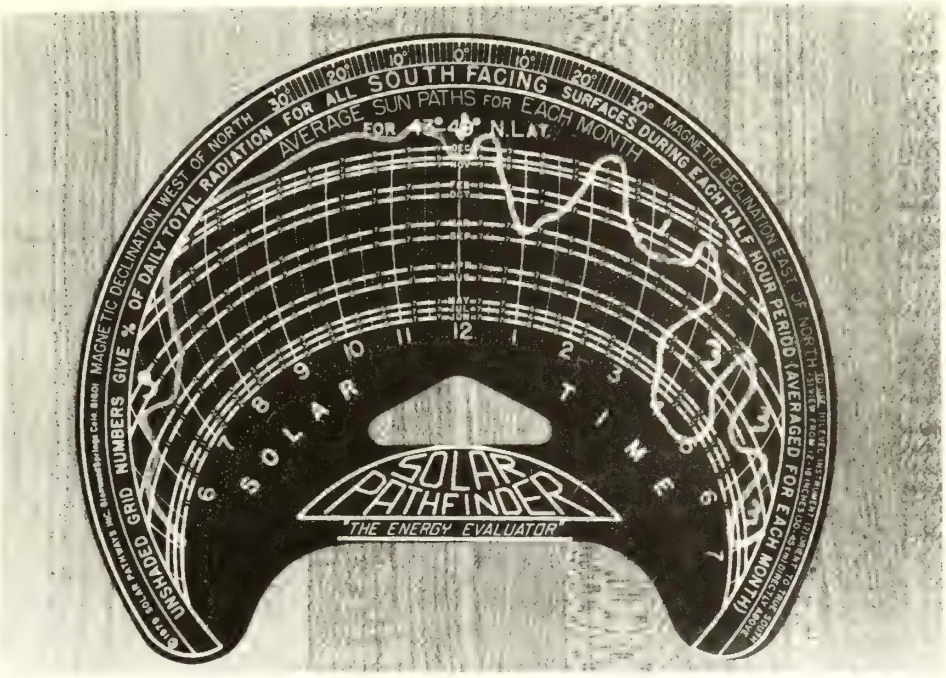

UNSHADED GRID NUMBERS GIVE % OF DAILY TOTAL RADIATION FOR ALL SOUTH FACING SURFACES DURING EACH HALF HOUR PERIOD (AVERAGED FOR EACH MONTH)
AVERAGE SUN PATHS FOR EACH MONTH
FOR 43°-49° N.LAT.
MAGNETIC DECLINATION WEST OF NORTH
MAGNETIC DECLINATION EAST OF NORTH
30° 20° 10° 0° 10° 20° 30°
6 7 8 9 10 11 12 1 2 3 4 5 6 7
SOLAR TIME
SOLAR PATHFINDER
THE ENERGY EVALUATOR
1
2
3

Figure 28—The sky-obstacle border with topographic (1), conifers (2), and deciduous (3) classified as to density. (1 = 100% winter and summer, 2 = 90% summer and winter, 3 = 80% summer, 45% winter.)

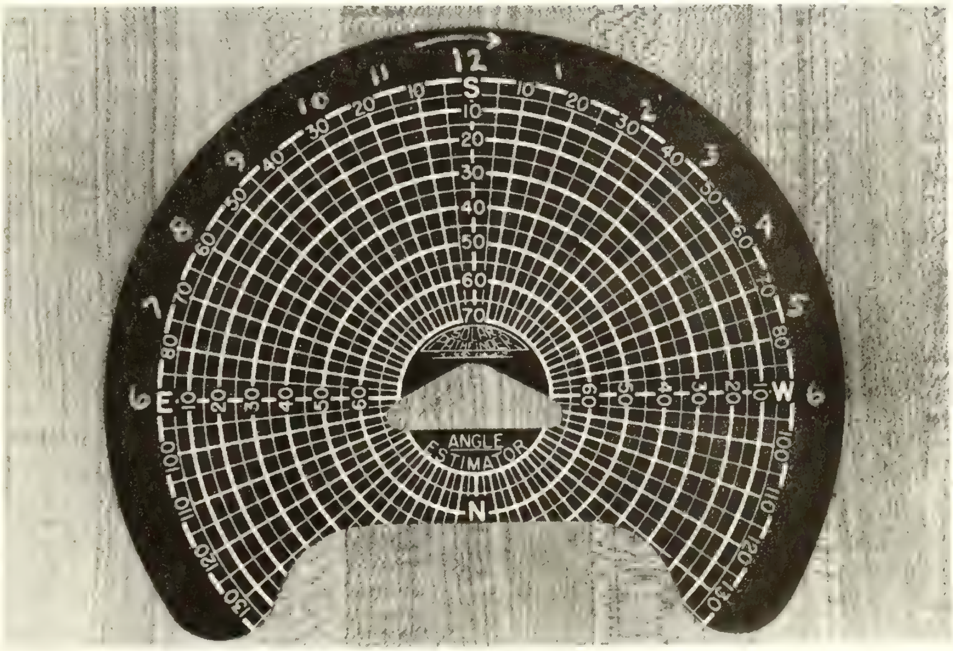

6 7 8 9 10 11 12 1 2 3 4 5 6
S
E
W
N
10 20 30 40 50 60 70 80 90 100 110 120 130
SOLAR PATHFINDER
ANGLE ESTIMATOR

Figure 29—The Solar Pathfinder^{TM} angle estimator graph with solar time recorded on it.

Thus, the observer could visualize what the consequences would be if trees or brush intercepting the sun's path were cut or burned. In addition, the observer could better visualize what type of plantings are needed to fill these holes that allow solar heat to directly enter the stream. Consequently, past, present, and proposed vegetative removal or even future vegetative growth can be effectively evaluated.

Table 16—The sun's altitude and azimuth at selected northern latitudes on August 1

Local standard time	Altitude angle (°)	Azimuth angle (°)
	35° N. latitude	
0800	34.5	-88.6
0900	46.7	-78.9
1000	58.4	-65.2
1100	68.4	-42.0
1200	73.0	0.0
1300	68.4	42.0
1400	58.4	65.2
1500	46.7	68.9
1600	34.5	88.6
1700	22.3	83.1
	40° N. latitude	
0800	34.3	-85.2
0900	45.5	-73.8
1000	56.1	-58.4
1100	64.5	-34.8
1200	68.0	0.0
1300	64.5	34.8
1400	56.1	58.4
1500	45.5	73.8
1600	34.3	85.2
1700	22.8	85.1
	45° N. latitude	
0800	33.7	-81.9
0900	44.0	-69.1
1000	53.2	-52.6
1100	60.2	-29.7
1200	63.0	0.0
1300	60.2	29.7
1400	53.2	52.6
1500	44.0	69.1
1600	33.7	81.9
1700	23.1	87.2
	50° N. latitude	
0800	32.8	-78.6
0900	42.0	-64.8
1000	50.0	-47.7
1100	55.8	-26.0
1200	58.0	0.0
1300	55.8	26.0
1400	50.0	47.7
1500	42.0	64.8
1600	32.8	78.6
1700	23.3	89.4
	55° N. latitude	
0800	31.7	-75.5
0900	39.7	-60.9
1000	46.5	-43.7
1100	51.3	-23.2
1200	53.0	0.0
1300	51.3	23.2
1400	46.5	43.7
1500	39.7	60.9
1600	31.7	75.5
1700	23.2	88.5

STREAMBANKS

A streambank is that portion of the channel-bank cross-section that controls the lateral movement of water. The bank often has a gradient steeper than 45° and exhibits a distinct break in slope from the stream bottom (fig. 30). Banks can also have a distinct change in substrate materials from those making up the bottom because of the different tractive forces and types of vegetation that control the scouring and deposition. Riparian vegetation plays an important part in controlling how the tractive forces form the streambank and in the degree of streambank stability. Therefore, riparian vegetation plays an important part in determining how the streambanks handle water and their ability to produce productive fisheries and high water quality.

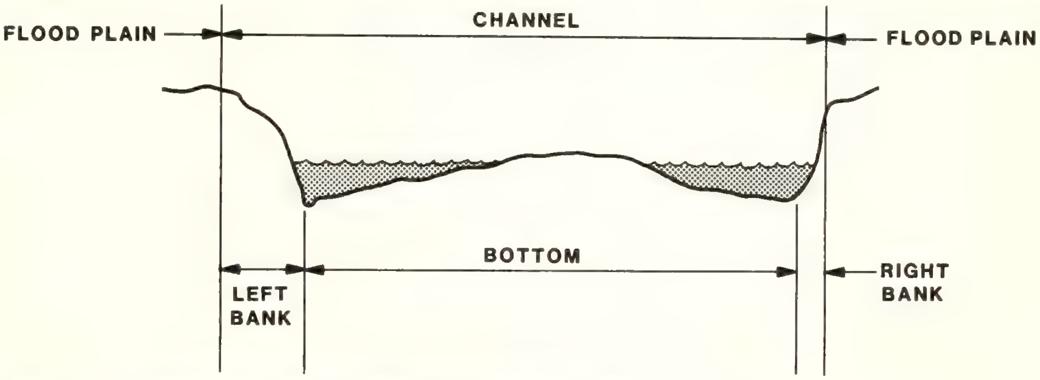


Figure 30—A well-defined stream channel with concentrated low flows and exposed bottom (downstream view).

Streambank and Channel Aggradation, Degradation, and Morphology

Streambank stability and form play a major role in determining the productivity of riparian ecosystems. Local streambank movement, through erosion and deposition, and morphology can be determined using the modified sag tape procedure developed by Ray and Megahan (1978). The streambank cross-sections can be plotted using the same horizontal and vertical scales to avoid exaggeration of bank-bottom features, or changed if banks need more detail for better analysis. This method identifies the techniques to determine both bank and channel form and movement, but the streambank can be measured separately if so desired.

The left bank is on the left side facing downstream. The cross-section profile readings should always begin at the left transect reference marker (preferably a metal stake driven into the ground) for consistency. This allows the computer to plot the left bank on the left side of the resulting graph. The readings start at the left transect stake and end at the right stake. If streambank or cross-section profiles are going to be recorded over a number of years, then the metal stakes should be driven at least 3 ft into the ground to prevent stake movement due to frost heaving. In addition, a permanent reference point that will not be affected by events that may affect the streambank, such as markers on large trees or bedrock knobs, should be established to determine whether the elevation of the top of each stake changes over time. Any movement of the stakes reduces the ability of the cross-section to accurately monitor streambank movements.

Data Collection—The data form (see appendix 3) contains space for 50 sets of cross-section measurements, with a continuation sheet for 50 additional measurements. Cross-section readings are separated by commas to form columns. Instructions for inputting data into field forms are:

Line No.—The number of the data statement to be used in the computer program. Leave this vacant until ready to input data.

Stream—Enter the name of the stream.

Location—Enter the location of the station being surveyed, with sufficient detail for it to be located later. This is only necessary when there are multiple study areas on the same stream.

Date—Enter the date. Single digit months and single digit days must be preceded by zeros. For example, May 2, 1985, is entered as 05/02/85.

Station—Enter the assigned stream code for the stream so that the data can be readily accessed by the computer.

Transect—Enter the number of the transect. Single digit transects must be preceded by a zero. For example, transect number 6 would be coded as 06.

Tension—Record the amount of tension being applied to the measuring tape, rounding to the nearest 0.5 lb.

T—Enter a code number for the type of tape being used. For example, enter a "0" for a tape of a certain weight per inch, a "1" for a tape of a different weight per inch, and so on.

M—Enter a code number for the type of water velocity meter being used. For example, enter a "0" for a certain electronic meter, a "1" for a certain cup-type meter, and so on.

Stake right—Enter the elevation of the right stake of the transect, accurate to no less than the nearest 0.01 ft, which provides an acceptable error of ±0.005 ft. Preferably measure to the nearest 0.001 ft. Both right and left stake elevations must be determined using the same level location. To reduce the time involved, position the level so that the maximum number of stake elevations can be determined from one stand. However, distance of more than 25 ft between level and rod may adversely affect accuracy. (See end of this chapter for more specifics.)

Stake left—Enter the elevation of the left stake of the transect, as with the right stake. Use the same accuracy of measurement.

Water-up and water-down—Enter the surface elevation of the water, at the center of the stream, upstream (water-up), and downstream (water-down) from the transect, rounding to the accuracy desired. Water surface elevations do not need to be taken from the same level location as the stake elevations, but once established, all water-up and water-down elevations should be taken at the same location. If the level stand must be moved, the previous water surface locations must be resurveyed from the new location before proceeding.

Distance—Enter the distance between the water-up and the water-down readings. The distance should be rounded to the nearest 0.1 ft. Take this measurement down the middle of the stream preferably using a 100-ft cloth tape. Distance measurements should be made in the middle of the stream. Using figure 31 as an example, the unitless measurement from point A to point B = 15.1, point B to point C = 20.0, point C to point D = 50.2, and point D to point E = 20.3. Adding the distances, the total distance between transect 26 and 35 = 105.6. The tape measurement should remain in the middle of the stream.

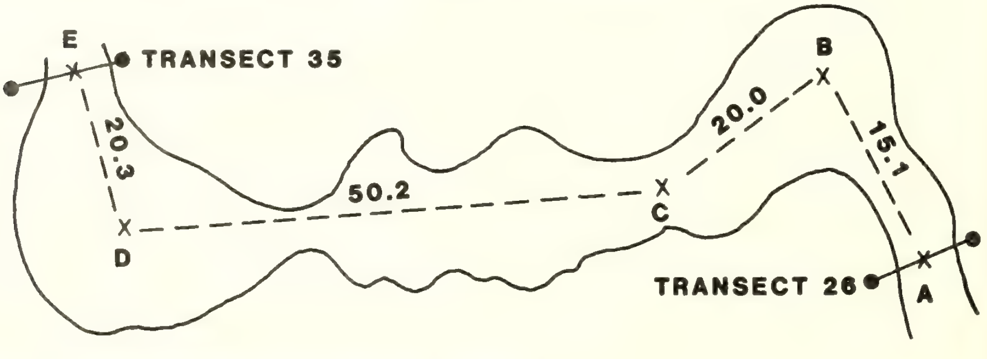


Figure 31—Measuring water-up and water-down distances.

Right bank undercut—Enter the width (distance cut into the streambank) of the right bank undercut to the nearest 0.1 ft. If more than one undercut exists, measure the dominant (usually the largest) undercut only.

Right bank height—Enter the height of the dominant right bank undercut, rounding to the nearest 0.1 ft.

Left bank undercut—Enter the width of the left bank undercut.

Left bank height—Enter the height of the left bank undercut.

Number of readings—Enter the number of sets taken across the transect. A set consists of a code number for the channel characteristic (C) (see following list), a code for the presence of water (W) (water = 1 and no water = 0), the horizontal tape distance, the distance from the ground to the tape, the depth of the water, and the water velocity. (Edge of water, can be recorded as channel characteristic = 6, water = 0 or water = 1; but do not enter a water depth with this entry.) Use space on the right side of the form to record more than one velocity reading. The channel characteristic codes are:

0 - Stake
1 - Between stake and top of streambank
2 - Top of streambank
3 - Streambank to channel bottom
4 - Edge of bottom or active channel
5 - Exposed bottom (no water)
6 - Edge of water
7 - Stream bottom.

Recording Cross-Section Survey Data—Start all measurements on the left bank. Attach the zero end of the measuring tape to a tension scale and center the tension scale handle over the end of the left transect stake. Stretch the tape across the stream to the right transect stake. After attaching the tape holder to the right stake, place the tape into the tape holder (fig. 32). Pull the tape until 10 to 20 lb of tension is obtained on the tension spring; on wide streams (>70 ft) more tension may be needed. Close the tension tape handle to hold the tape in place. Record the spring tension on the field form to the nearest 0.5 lb and check it periodically for slippage. If it slips, start again. The tape must not touch anything along its entire length, including the water, because its sag will be affected. In addition, windy conditions will affect both tape sag and tension, and should be avoided.

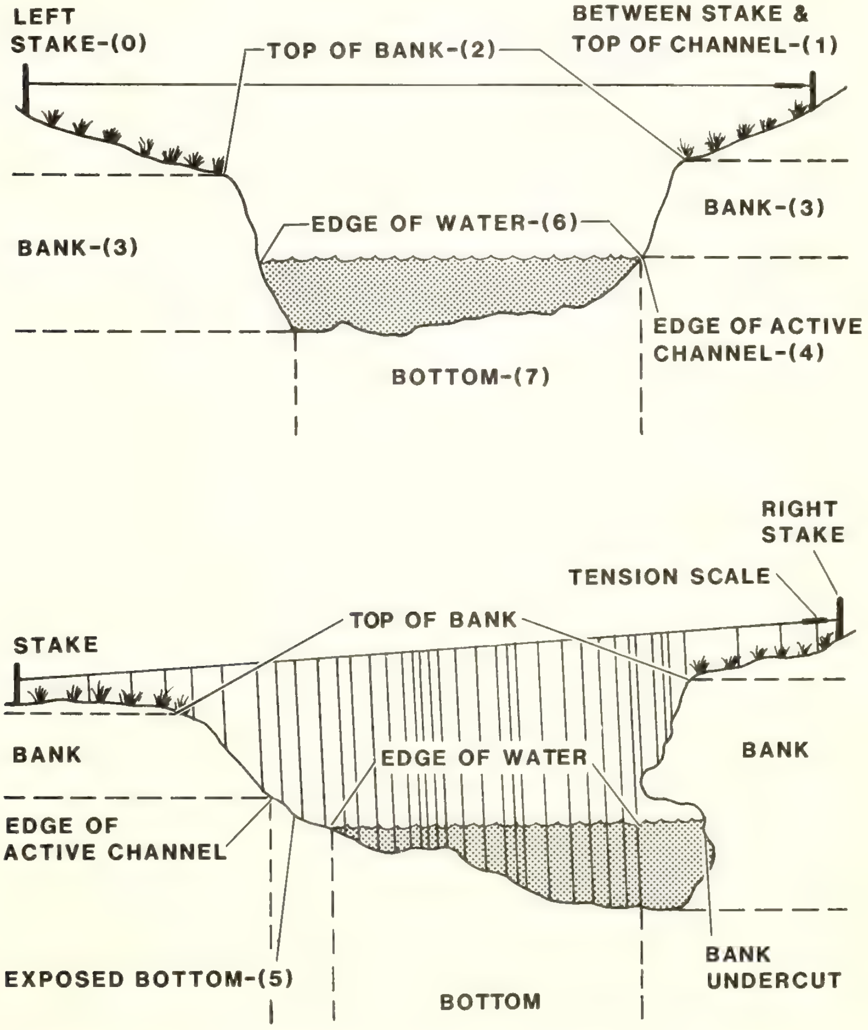

LEFT STAKE-(0)
TOP OF BANK-(2)
BETWEEN STAKE & TOP OF CHANNEL-(1)
BANK-(3)
EDGE OF WATER-(6)
BANK-(3)
EDGE OF ACTIVE CHANNEL-(4)
BOTTOM-(7)
RIGHT STAKE
TENSION SCALE
TOP OF BANK
STAKE
BANK
EDGE OF WATER
BANK
EDGE OF ACTIVE CHANNEL
EXPOSED BOTTOM-(5)
BOTTOM
BANK UNDERCUT

Figure 32—Example of stream channel morphological descriptions.

Measure the vertical distance between the top of the left stake and the tension scale handle where it touches the back of the stake, using a pocket tape. Record this distance on the form as a negative vertical distance in the "To Tape" column. Measure the vertical distance from the tension handle to the ground; use the hand level to position the tape at a 90° angle with the tape and pocket tape as needed. Record this positive reading as the second "To Tape" measurement on the form. Be sure to record the negative reading first, then the positive.

Proceed with the cross-section measurements making vertical measurements to the nearest 0.01 ft and all horizontal readings to the nearest 0.1 ft. Measure the horizontal distance between the stake and the zero mark on the steel tape and record this distance as a negative number in the first two "Distance Horizontal" entries on the form. This measures the length of the tension scale. Continue the survey across the entire cross-section, recording corresponding vertical and horizontal measurements and water depths. Take all vertical measurements on the downstream side of the tape. Use the hand-held rod level to make sure that each horizontal measurement is taken at a 90° angle to the water surface and tape to minimize your effect on water flow.

When proceeding across the channel, readings are taken wherever breaks in the slope of the channel surface occur, at the top of the channel sides, at the edges of any exposed bottom, and the edge of the water surface (fig. 32). Be sure to take the appropriate measurements on any islands in the stream. Record the channel characteristics for each measurement point using the channel characteristic codes listed previously.

Upon reaching the right streambank, record the right stake height above the tape holder (negative number) and below (positive number) as on the left bank; again, record the negative reading first. Use the same horizontal reading for both vertical measurements.

The bank channel characteristics to be measured are:

Channel—That portion of the cross-section containing the stream that is obviously distinct from the surrounding area due to breaks in the general slope of the land.

Edge of channel—That point at the bank-channel intercept where the break in the general slope of the land occurs.

Bank—The portion of the cross-section that restricts lateral movement of water. The bank usually has a gradient steeper than 45° and exhibits a distinct break in slope from the stream bottom. Also, an obvious change in stream bottom substrate may be a reliable delineation of the bank.

Stream bottom or active channel—The portion of the channel between the banks, where annual bedload transport occurs.

Exposed bottom—The nonwetted portion of the stream bottom. The recorder must indicate whether measurements are made in the water column (0 = no water, 1 = water). Record the obvious points of the stream channel with the appropriate characteristic code.

Elevation—Position the engineer's level so that you can shoot the maximum number of transects from the same location; this reduces cost and time. The right and left stakes of any one transect must be shot from the same place. Sink the tripod feet into the ground to stabilize the instrument and level with the built-in leveling bubble. Be sure the instrument remains level when the scope is turned in any direction. Once the instrument is set, do not bump the tripod or level.

Have someone hold the level rod on the top of the stake being surveyed. Make sure that the rod is as perfectly vertical as possible by using a hand-held rod level placed against it. Read the number corresponding to the middle cross hair and estimate the number to at least the nearest 0.01 ft, preferably to the nearest 0.001 ft. Record this number in the appropriate space on the data form and reread to verify. Be sure to read only the middle cross hair. The level can be located on either side of the stream because all that is needed is the relative difference in elevation between right and left stakes. If brush or trees are in the way, a third person could hold them back or perhaps they could be tied out of the way. Accuracy to 0.01 ft can even be obtained by some waving of the rod under these conditions. After surveying a group of stakes, determine the water-up and water-down elevations with the level rod held in the middle of the stream on the water surface. These elevations need not be taken from the same place as the stakes. The distance between the water-down and water-up on elevation recording sites needs to be measured to calculate channel gradient.

To read the level rod, note that the large red numbers are in feet, the smaller black numbers are in tenths of feet, and the black marks between the tenths are in hundredths (see figures to determine how to read hundredths). Thousandths of feet must be estimated between the hundredths marks (fig. 33).

Checklist of Hydraulic Geometry Equipment—

1. Engineer's level, tripod, level rod, and bubble rod level
2. Measuring rods (5 ft and 10 ft) marked in 0.1-ft intervals for undercut measurement
3. 100-ft cloth tape
4. 200-ft steel tape and clamp
5. Two 6-ft pocket tapes measuring to 0.01 ft
6. Tension scale (pounds)
7. Metal clipboard and field data forms
8. Folder for completed forms
9. Mechanical pencils with erasers and spare lead
10. Hip and chest waders
11. Methodology manual.

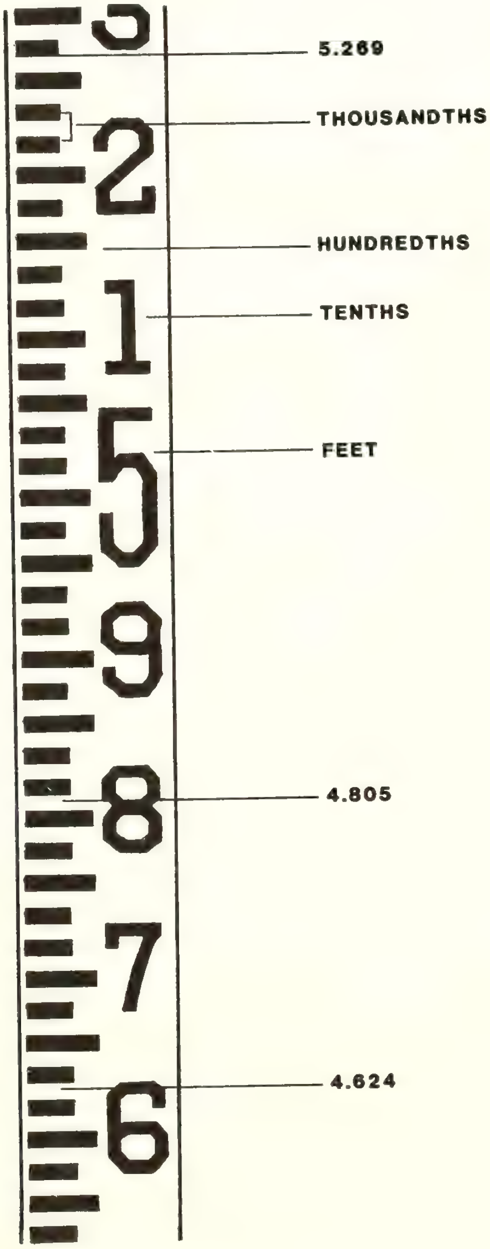


Figure 33—Example of a level rod.

Streambank Soil Alteration

Certain land uses, such as roading, logging, and livestock grazing, can start the modification of a stream by causing instability of the bank. Therefore, this streambank alteration rating may provide a warning system for changes that could eventually affect fish populations.

The streambank alteration rating reflects the changes taking place in the bank from any force (table 17). The rating is separated into five classes. Each class, except the one with no alteration, has an evaluation spread of 25 percentage points. Once the class is determined, the observer must decide the actual percentage of instability. Streambanks are evaluated on the basis of how far they have moved away from optimum conditions for the respective aquatic habitat type. Therefore, the observer must be able to visualize the streambank as it would appear under optimum conditions. Any natural or artificial alteration deviating from this condition is included in the evaluation. This visualization makes uniformity in rating an alteration difficult because it is difficult to train all observers to visualize the same optimum bank condition. Natural alteration is any change in the bank produced by natural force. Trampling by people or livestock and disturbance by bulldozers or trucks are examples of artificial methods that can alter streambank soils and form.

Natural and artificial alterations are reported individually, but together they cannot exceed 100 percent. To reduce the confidence intervals, only that part of the streambank intercepted by the channel cross-section transect line enters the evaluation. Channel cross-section transect lines have no end. The line crosses both streambanks as the channel transect line is extended. Rating the complete bank as a unit between groups of transects in our studies resulted in greater observer error.

It is commonly difficult to distinguish artificial from natural alterations. It is possible to have artificial alterations cover already existing natural alterations and vice versa. In such case only the major type of alteration on a unit area enters the rating system. If there is any doubt, the alteration is classified as natural.

The cross-sectional profile methods discussed earlier can help with the evaluation of the major alteration. However, the profiles do not determine whether changes in the streambank are caused by natural or artificial forces. Because the 95 percent confidence interval (±12.3 percent) around the mean and observer variation is quite wide, interpreting the data must be done carefully. Between the test streams studied, there was a wide spread in the precision and accuracy of measurements. Overall precision was rated fair to good, but accuracy was rated mainly poor to fair. Therefore, caution should be used in evaluating the data from this measurement.

Table 17—Streambank soil alteration rating

Rating	Description
Percent	
0	Streambanks are stable and are not being altered by water flows, animals, or other factors.
1 to 25	Streambanks are stable but are being lightly altered along the transect line. Less than 25 percent of the streambank is receiving any kind of stress, and if stress is being received, it is light. Less than 25 percent of the streambank is false,[1] broken down, or eroding.
26 to 50	Streambanks are receiving only moderate alteration along the transect line. At least 50 percent of the streambank is in a natural stable condition. Less than 50 percent of the streambank is false, broken down, or eroding. False banks are rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
51 to 75	Streambanks have received major alteration along the transect line. Less than 50 percent of the streambank is in a stable condition. Over 50 percent of the streambank is false, broken down, or eroding. A false bank that may have gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
76 to 100	Streambanks intercepted by the transect line are severely altered. Less than 25 percent of the streambank is in a stable condition. Over 75 percent of the streambank is false, broken down, or eroding. A previously damaged bank, now classified as a false bank, that has gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.

---

[1] False banks are those banks that have been cut back by some artificial force and are no longer immediately adjacent to the stream. They can become stabilized by vegetation, but base flows are usually too far removed from the stream to provide fish cover.

treambank ndercut

Streambank undercut provides cover for fish and is a condition favorable to producing high fish biomass, especially in small streams. Undercut is a good indicator of how successfully streambanks are protected under alternative land uses, such as livestock grazing and road building. The undercut, if it exists, is measured with a measuring rod to the nearest 0.1 ft directly under the transect line from the farthest point of protrusion of the bank to the farthest undercut of the bank (fig. 34); water level does not influence this reading. If more than one undercut occurs under the transect, only the dominant (usually the larger) undercut is recorded.

The 95 percent confidence intervals around the means (±18.5 percent) are wide. However, year-to-year precision and accuracy are good. The major cause of the wide confidence interval is that the two points that define the undercut measurements are difficult to accurately determine. Then, too, a naturally high variation exists in size of undercuts.

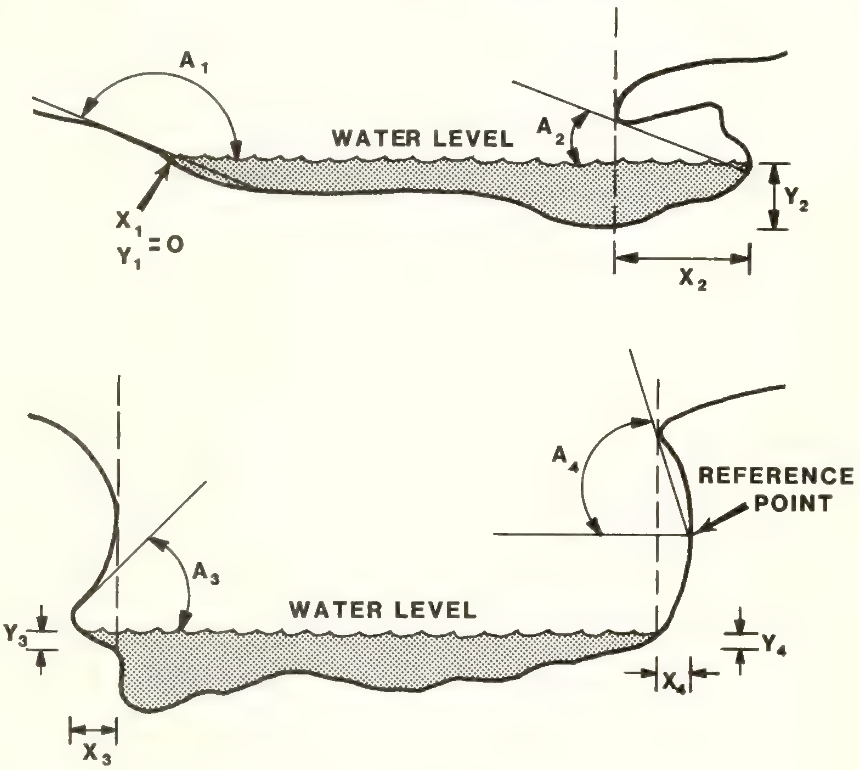


Figure 34—Hypothetical channel cross sections illustrating bank angle (A), undercut (X), and water depth (Y) measurements.

ream Shore ater Depth

The stream shore water depth is critical for fish, especially young-of-the-year (figs. 34 and 35). Also, the following measurement is effective in evaluating riparian use activities that could modify the streambank and its riparian vegetation.

The water depth at the stream shore is measured at the shoreline or at the edge of a bank overhanging the shoreline (see fig. 34, angle A1). If the angle formed by the bank as it meets the stream bottom is over 90°, the stream shore water depth reading is always zero. If the angle is 90° or less, the water column goes under the streambank and the measurement of the stream shore water depth is greater than zero (see fig. 34, angles A2, A3, and A4). The measurement is taken to 0.1 ft, and the measurements for both shores can be totaled and averaged for an overall rating for the transect or kept separate so each bank condition can be followed.

Because of the variation in stream shore depth, the test sample had a 95 percent confidence interval about the mean of ±16.6 percent. These intervals were fairly wide because of the high variability and the difficulty in standardizing the technique. However, we did find that the precision and accuracy were good from year to year.

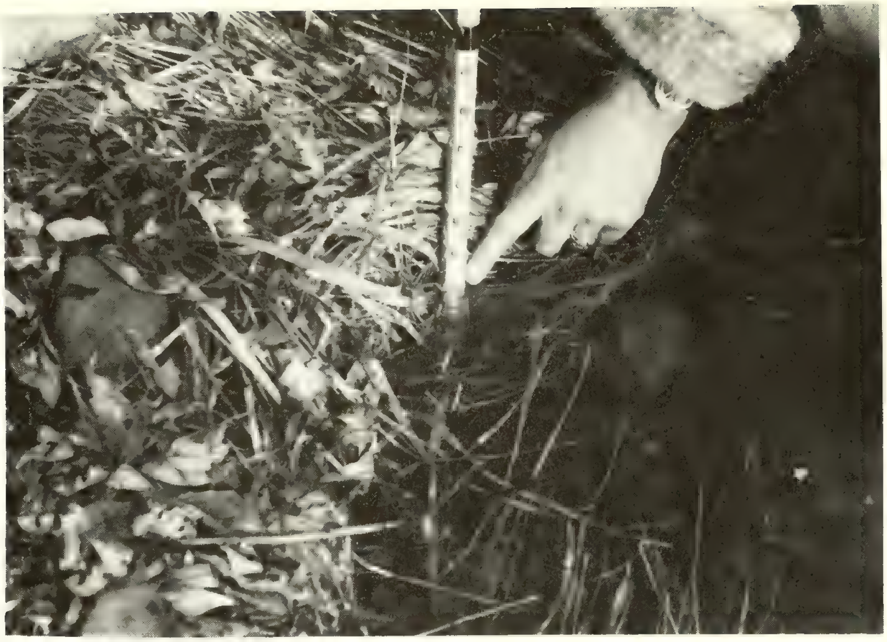


Figure 35—Measuring stream shore water depth.

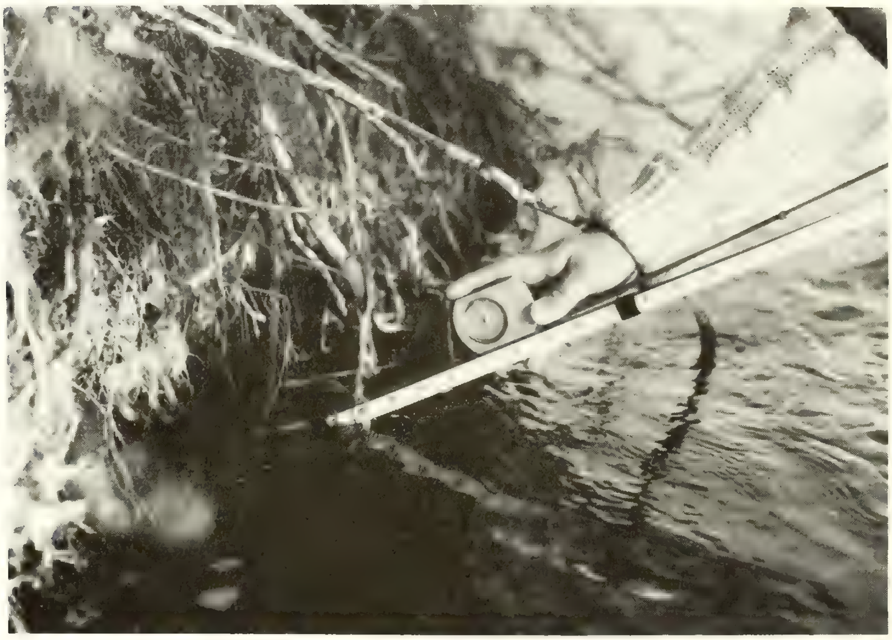


Figure 36—Using a clinometer to measure a bank angle of 45°.

Stream Channel-Bank Angle

Fish often congregate near the streambank for the cover it provides. If the bank has been cut away and moved back from the water column, valuable rearing habitat has been lost. Measuring the channel-bank angle is effective for monitoring land uses that can change the morphology and relative location of the streambank.

A clinometer is used to measure the angle formed by the downward sloping streambank as it meets the more horizontal stream bottom. When the streambank is undercut, the angle is always less than 90°. The angle is determined directly from the clinometer placed on the top of the rod as it forms the angle determined by the protruding edge of the bank to the midpoint of the undercut under the transect line (fig. 36).

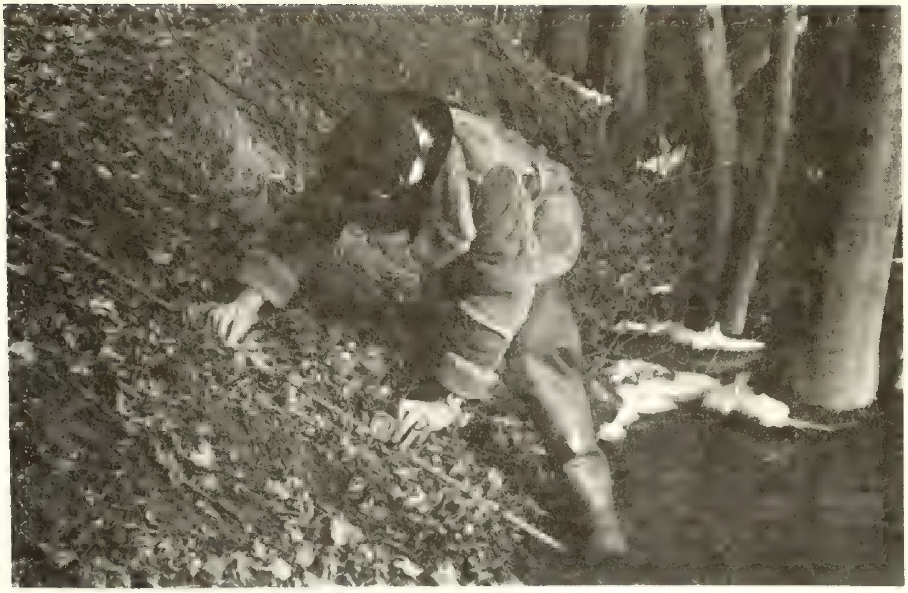


Figure 37—Using a clinometer to measure a bank angle of 145°.

When the bank is not undercut, the angle is greater than 90° and is measured from the bank side by placing the clinometer on the top of the measuring rod aligned parallel to the streambank along the transect (fig. 37). The clinometer reading is subtracted from 180° to obtain the bank angle.

A streambank angle greater than 90° is easily read with precision and accuracy. An angle less than 90° is more difficult to read as multiple undercuts can complicate the bank profile, making it difficult to determine the points delineating the angle. The key is to include the midpoint of the dominant undercut in the bank profile. The 95 percent confidence intervals around the means are quite narrow (±4.4 percent), and year-to-year precision and accuracy are good.

MEASURING AND MAPPING ORGANIC DEBRIS

Organic debris originating in a riparian area plays an important role in the character and productivity of streams. The size and type of material determine the effect on channel morphology as well as its distribution in the stream. Organic debris ranges from green trees to decomposed wood or naturally occurring material to logging debris. Organic debris ranges in size from fine pieces to whole trees. The agents that put debris into streams vary from leaf drop during autumn to single-tree blowdown, windfall of several trees, or massive debris avalanches originating on steep slopes. To describe the effects of organic debris on channel morphology, the amount and type of material along the riparian area and in the stream channel should be measured with techniques that are defined and consistent within a study.

In this section we provide an array of methods to measure organic debris in streams. We present several methods that may be modified to the needs of the user. All of the methods have been used in one form or another. As with most techniques, the best method is the one that satisfies the objectives of the study.

Measuring Woody Debris in Stream Channels

One of the reasons for measuring organic debris in streams is to evaluate its effect on fish habitat. Streamside vegetation and its contribution to streams is an integral part of forest and aquatic ecosystems and must be considered in flood plain management and timber management. Among the considerations in debris management are the effects of changes in the recruitment rate of woody debris during and following logging, and methods to maintain debris loading levels that will continue to provide usable fish habitat.

The most easily observed effects of organic debris are those on stream channel morphology, where large pieces of debris are associated with a specific habitat feature such as a log dam and a plunge pool or a single log or tree forming a deflector and backwater pool.

In addition, allochthonous organic debris may function as the primary source of organic carbon in the nutrient budget of streams, particularly small woodland streams (Triska and Sedell 1975; Naiman 1982; Bilby and Likens 1980). Other management considerations include blocks to migration that must be balanced against the function of debris as in-stream habitat (Baker 1979).

Once a study reach within a stream system has been selected, the channel boundaries must be defined. Swanson and others (1984) defined the edge of bank on the basis of the mean annual flow. But this is difficult to define except by observing the edge of streamside vegetation, water marks, or an abrupt, steep bank. The purpose is to define a boundary including debris that will directly influence channel morphology and the habitat of aquatic organisms. The length of the sample area will depend on the nature of the survey, but the length should be proportional to the channel width. Keller and MacDonald (1984) used a length of 20 to 30 channel widths to define their sample area.

The effect of organic debris and the methods used to measure it depend upon the size and type of material as well as the objectives of the survey. Woody debris is measured using the metric system and may be separated into two categories: (1) large woody debris, including material greater than 1 m in length and with a diameter at one end greater than 10 cm, and (2) coarse woody debris that includes material smaller than larger woody debris, but larger than 1.0 mm in diameter. Material smaller than this is generally grouped into either fine particulate organic matter—between 0.45 mm and 1.0 mm in diameter—or dissolved organic matter—less than 0.45 mm (table 18).

Size categories may be defined in relation to the effects. For example, effects on stream channel morphology could be described by the size and orientation of individual pieces or of accumulations.

The amount of debris can be described as biomass (weight or volume), number of individual pieces, or percentage of stream area covered. For comparisons among streams, measurement of the amount of debris is usually reported in the metric system as volume (cubic meters) or weight (kilograms) per unit area (square meters). Weight or volume of debris may not be as descriptive of fish habitat as density or number of accumulations along a stretch of stream. Type of material and its location in the stream may be more important to fish habitat than are weight and volume of material. Counts of pieces of debris should be stratified to describe the type of material and its location in the stream (table 19).

In most studies of debris loading, stream-to-stream comparisons are made with biomass or weight per unit area (Keller and Talley 1979; Keller and MacDonald 1984; Triska and Cromack 1980; Bryant 1981; Swanson and others 1984). Most of these estimates were

Table 18—Categories commonly used to classify organic debris

Abbreviation	Definition
DOM	Dissolved organic material less than 0.02 inch in diameter
FPOM	Fine particulate material greater than 0.02 inch but smaller than 0.04 inch in diameter
CPOM	Coarse particulate material greater than 0.04 inch but smaller than 3.9 inches in diameter
LOD	Large organic debris material greater than 3.9 inches in diameter

Table 19—Size categories used to estimate debris volume in streams (adapted from Froehlich and others 1972)

Category	Size range (diameter)	Average diameter
	Centimeters	
Fine	less than 1	0.423
Twigs	1 - 3	1.792
Branches	3 - 10	5.049
Coarse	greater than 10 in diameter and 30 in length	

derived from counts or measurements of individual pieces along a transect line across the stream channel. Individual pieces of large organic debris (LOD) were scaled to obtain volume. Estimates of volume in cubic meters were multiplied by the estimated specific gravity of the wood in the stream (0.5) to obtain biomass in kilograms per square meter (Talley 1980).

These methods, developed by Van Wagner (1968) for measurement of forest residue and adapted by Froehlich and others (1972) and Lammel (1972) to measure woody debris in streams, stratify debris into three size categories (table 19). DeVries (1979) details the theory of line transect sampling upon which the method is based.

Pieces of debris less than or equal to 10 cm in diameter are stratified into three size classes and are counted along a line transect across the stream. Volume of debris in each size class is computed by (Van Wagner 1968):

$$V = \frac{(\pi)(\sum n_i d^2)}{8L}$$

where:

n is the number of pieces in a size class along the transect line

d is the average diameter of the size class from table 19

L is the length of the transect line.

Transects perpendicular to the stream flow were established at regular intervals along the study reach by Froehlich and others (1972) and Lamell (1972) in Oregon and Swanson and others (1984) in Alaska. In most cases 25 percent of the transect was sampled in 30-cm lengths randomly selected along the transect. The researchers counted all sticks that intersected the vertical plane under the 30-cm line in each of the three size classes. In shorter transects or where fine debris was sparse, they counted all pieces along the transect.

The volume of all pieces of debris greater than 10 cm diameter was estimated throughout the sample section. Each end (d_1 and d_2) of the piece was measured with large calipers (fig. 38). A meter stick or fiber tape was used to measure length (L). The researchers did not include the section of the piece outside of the "in-stream boundary." They computed volume (V) using the formula:

$$V = [\pi (d_1^2 + d_2^2)L]/8$$

Weight was computed by multiplying the volume by 0.5, the estimated specific gravity for softwood (Talley 1980; Swanson and others 1984). Total biomass for the section was computed by summing the weight of all pieces in the section.

Scaling debris to obtain volume and weight is time consuming. Counts of individual pieces or accumulations can provide both quantitative and qualitative descriptions of LOD in streams. In the example in table 20, the counts are made along a reach and compared as

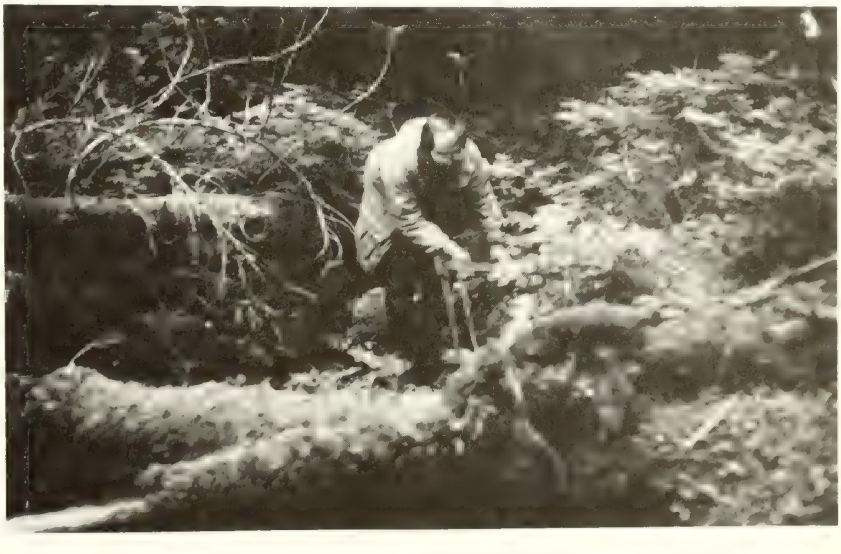


Figure 38—Measuring debris with calipers.

number of accumulations per area or linear distance. Root wads are considered separately in this example and are separated by their location in the stream channel. Counts can be made "on the ground" by direct observation, from aerial photographs, or from scale maps. Bishop (1968) used debris counts and low-level aerial photography to describe LOD (greater than 15 cm in diameter) in Big Creek on Prince of Wales Island, southeast Alaska, over a 4-year period before and after logging. Bryant (1980) made counts of individual pieces or accumulations of debris using maps to show changes in debris loading in Maybeso Creek on Prince of Wales Island.

A more subjective system, based on percent of stream channel length affected by different size classes of debris, was developed by Silvey and others (1977) to evaluate debris loading and channel condition following fires. They used size class of debris and percent of channel length affected to derive an index of in-stream debris loading. Table 21, derived from the data sheet given by Silvey and others (1977), shows that larger material such as logs and root walls is given a greater weight than smaller material such as needles and twigs. The index is computed by multiplying the loading rating observed in each size category by the number of miles of channel surveyed and summing to obtain a total. The total can be divided by number of miles to standardize the measure. For example, if one debris jam—category IV—was observed and 10, 25, and 8 percent of 5 miles of stream were affected by debris in categories I through III, respectively, then the index shown in

Table 20—Tally sheet for large debris counts divided into size of accumulation and position in the stream

Size of accumulation	Number of accumulations across the stream		
	Less than 1/3	**1/3 - 2/3**	**More than 2/3**
Number of pieces:			
Less than 4			
5-10			
More than 10			
	Along bank	**Midchannel**	
Number of root wads:			
Cut			
Uncut[1]			

[1]Root wad attached to tree.

Table 21—Categories and weights used to compute the debris loading index of Silvey and others (1977)

	Size category	Length of channel affected	Weighting factor (WF)	Index (miles × WF)
		Percent		
I.	**Fines**: Ash, needles,	0-10	Low	1
	twigs, and pieces less	11-30	Med	2
	than 5 cm average diameter	30+	High	3
II.	**Coarse**: Branches,	0-10	Low	4
	limbs, and pieces	11-30	Med	6
	5-20 cm diameter up to 2.5 m length	30+	High	9
III.	**Heavy**: Logs, trees,	0-10	Low	5
	branches, stumps and	11-30	Med	10
	pieces greater than 20 cm	30+	High	15
IV.	**Debris** "jams" Existing or potential block	Number	High	10

Table 22—Sample data matrix for computation of debris loading indices

Size category	Length of channel affected	Weighting factor	Index
I	10 (low)	1	5
II	11-30 (med)	6	30
III	10 (low)	5	25
IV	(1)	10	50
Total		22	110

table 22 would be computed with the system shown in table 21. Then the index would be computed by multiplying the weighting factor by 5—the number of miles of stream surveyed—to obtain a total index for the stream of 110, or 22 per mile of stream. Silvey and others (1977) obtained indexes from 7.0 to 57.3 per mile for the streams they surveyed in California. A different range of values would be expected from streams in Idaho or Alaska.

Spacing and orientation of coarse debris may have a greater effect on channel morphology and aquatic habitat than does volume of debris alone. Several methods are available to evaluate these effects. To determine relative stability of pieces, the angle between the direction of flow and the most stable (anchored) end of the log may be measured. These data may be translated into an index of stability such as that suggested by Bryant (1983), or individual logs may be tagged and remeasured periodically to determine movement within the channel.

Position in the stream will largely determine the stability of large woody debris (LWD) and its use by fish as habitat. Individual logs may be grouped into categories to describe their position in the stream. Michael Murphy (personal communication) of the National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, AK, used four categories—complete bridge, collapsed bridge, ramp, and drift (fig. 39). The order is in decreasing stability and describes the association with the bank. Individual logs or accumulations of LWD may be stratified with respect to position in the stream (say, midchannel or adjacent to the bank) when LWD is related to fish habitat. The effect of a piece of debris may be recorded for the study reach. Keller and MacDonald (1984) used this technique in addition to measurements of debris volume. They compared pool-to-pool spacing (measured in channel widths), percent of channel with debris-stored sediments, percent of pool morphology influenced by debris, and debris-controlled drop in elevation of the channel.

LWD can have a significant effect on channel morphology, and in some studies it may be important to stratify pieces or accumulations by their effect on the channel. The strata are similar to those used by Keller and MacDonald (1984) and are (1) pool, (2) sediment storage, (3) flow deflection, and (4) no effect. These strata may be used to describe the potential effect on channel morphology as related to fish habitat or densities. In many cases, pieces having no effect may be classified as potential additions, such as pieces suspended above the stream that will eventually drop into the channel.

In summary, among the several methods to measure organic debris in streams are percentage area of stream affected, counts of individual pieces or accumulations, direct measurement to estimate volume or biomass, and measurement of the effect on the channel. There is also measurement of the location and orientation of individual pieces. But no one best method exists, except the one that fits the objective of the survey or study within time and budget constraints.

Obviously, a visual estimate of the percentage area of a stream affected by debris is less precise than an estimate of volume computed by the methods discussed here. It is also less time consuming. A more precise method may be combined with a "survey level" method to provide point estimates of debris loading or specific effects of debris along a stream reach. Stream mapping showing specific locations of debris and habitat types associated with debris will provide a better description of the stability and effect of large debris on channel morphology and fish habitat.

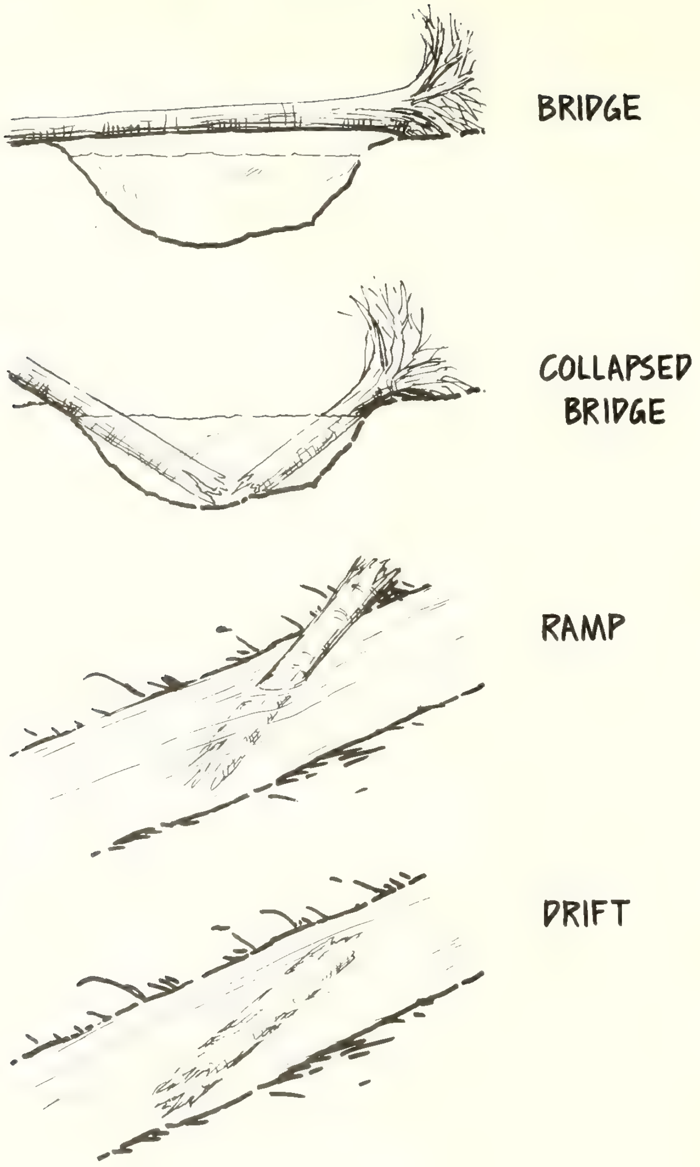


Figure 39—Four categories of large woody debris formations in streams.

Mapping Debris

Maps of stream channels can provide a useful base of data from which to evaluate effects of debris on channel morphology. Bryant (1980), Lienkaemper and Swanson (1980), and Keller and MacDonald (1984) provide examples of studies that use stream maps to identify effect of organic debris and effects of management activities on streams through changes in debris loading. In addition to the visual association between a debris formation and a specific morphological feature, maps provide a visual historic record of changes in debris location within a stream and its effect on channel morphology.

Mapping methods can vary in accuracy from a free-hand sketch of a stream reach to plane-table and aledaide measurements—time and accuracy are the constraints. A map of debris in a stream channel will identify the relative location of the piece or accumulation within the stream reach, but a known reference point must be established for the map. This can be a natural feature such as a bedrock outcrop or a large identifiable tree or boulder, or it can be a reference transect marked with stakes.

Two methods will be discussed. The first uses a fiber measuring tape, measuring rod, and compass. The second uses engineering surveying equipment. In both cases the basic principle is to establish a distance from a known point and an angle from a reference line along the stream. The former method is suitable for smaller streams generally less than 10 ft wide, whereas in a larger stream, surveying equipment increases both speed and accuracy.

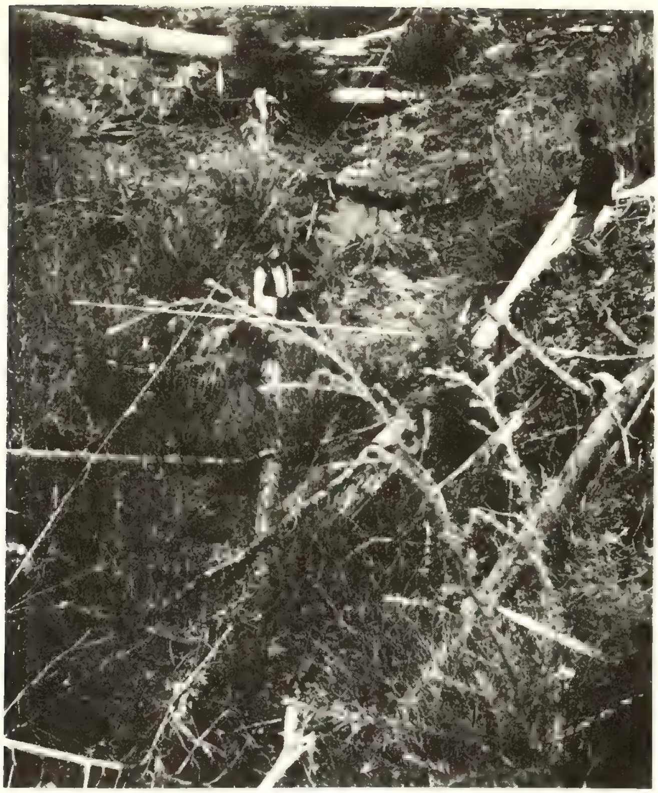


Figure 40—Stream mapping with tape and rod.

Graph paper simplifies the mapping procedure when using the tape, compass, and measuring rod method.

The tape is extended in a straight line along the stream to a convenient length, determined by the course of the stream and the scale of the map (fig. 40). In the example in figure 41, a 40-ft section of stream is mapped on 10-squares-to-the-inch graph paper with one square equal to 1 ft. A compass reading is taken along the length of the tape. The center line is at 110° in figure 41. The measuring rod is set horizontal to the stream and perpendicular to the tape. Measurements to the bank are made along the tape with the measuring rod. Intervals can be varied to reflect desired detail or significant in-stream features such as large rocks, root wads, points of gravel bars, or backwater areas. Edge of bank and edge of water are recorded at each interval. Pieces of debris, logs, trees, and so forth, are identified as they intersect transect lines. Diameters, lengths, and heights from the stream surface should be recorded on the rough map or field notes.

The map in figure 41 was constructed on an acetate overlay on graph paper. Acetate can be used in wet weather and offers a distinct advantage over mapping directly on graph paper. Details on the map were filled in from field notes on the "rough" map. The scale, orientation, field personnel, and legend are included on the map.

For larger streams and rivers, surveying equipment will give the best results. A transit and stadia rod or electronic distance meter (EDM) and theodolite can accurately establish distance from a known point and angle from a given reference line along the stream section to be mapped. A tape and compass can be used but are less accurate. Because errors (such as sag in the tape) are cumulative, maps of larger areas may be extremely distorted when a tape is used.

Data may be recorded in a field notebook as shown in table 23 or on a rough sketch drawn in the field (fig. 42). A rough map, although it may be distorted, is often helpful in reconstructing the scale map. If a rough map is not constructed, then accurate notes should be taken so that points can be interpreted correctly in the office. The final map in figure 43 was reconstructed from the distance and angles measured with the EDM recorded in the data book and the rough map shown in figure 42. The rough map and the notes provide the

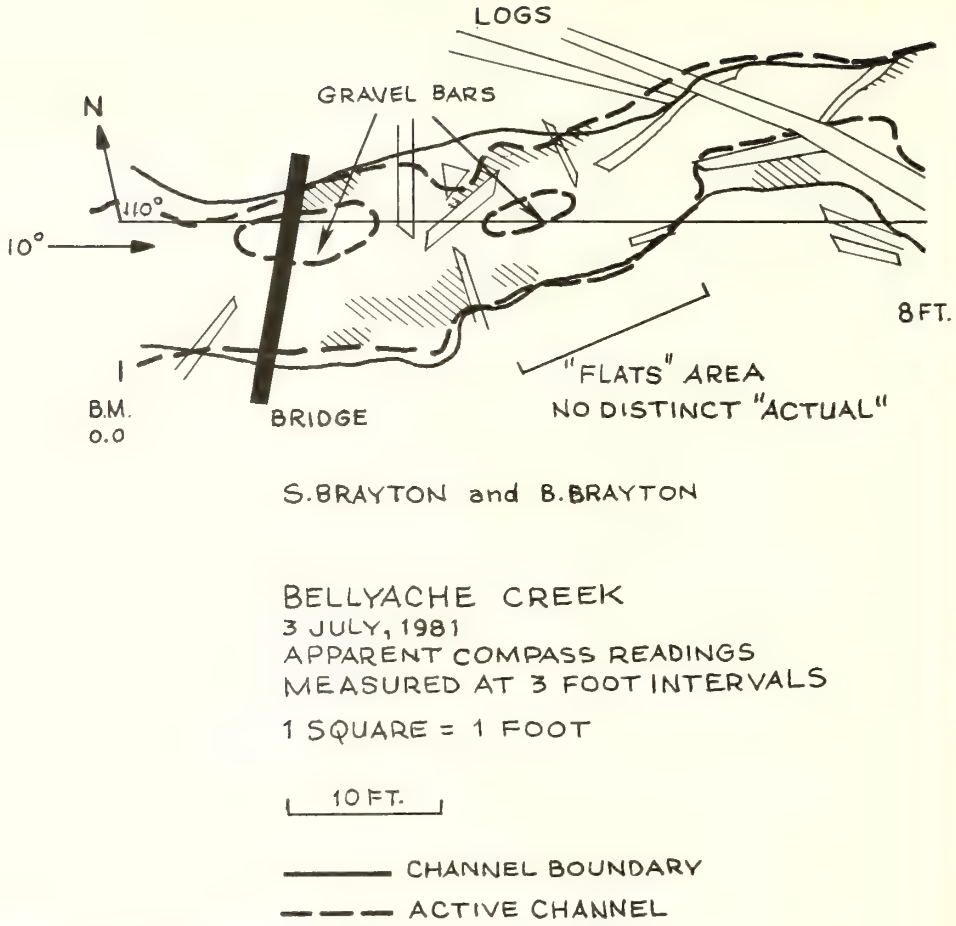

LOGS
GRAVEL BARS
N
110°
10°
8 FT.
I
B.M.
0.0
BRIDGE
"FLATS" AREA
NO DISTINCT "ACTUAL"
S. BRAYTON and B. BRAYTON
BELLYACHE CREEK
3 JULY, 1981
APPARENT COMPASS READINGS
MEASURED AT 3 FOOT INTERVALS
1 SQUARE = 1 FOOT
10 FT.
CHANNEL BOUNDARY
ACTIVE CHANNEL

Figure 41—Map constructed using the fiber tape and measuring rod technique.

Table 23—Partial list of EDM readings used to draw figure 43

Distance	**Angle**	**Remarks**[1]
Meters	*Degrees*	
11.4	0	RB, EB, end upstream sect
15.5	44°44′	RB, EW
24.4	69°43′	LB, EB, EW, end sect 1, begin BW
22.5	81°13′	End BW
20.5	76°03′	Mouth BW, EW
19.4	86°50′	Log #1
15.7	95°02′	Log #, EW, LB
21.0	133°27′	End debris, LB
15.7	143°43′	End debris, BW, EW (alder on debris)
9.6	157°00′	Log #1, end debris
12.2	187°57′	Log #1, over water
15.3	200°57′	Mid. debris
17.5	213°10′	End debris, water behind
20.2	213°46′	Log #2 end, begin R. channel
23.5	217°29′	Submerged logs, EW
30.1	227°54′	EW, GB, log #3
33.4	221°01′	End log #3, end BW
31.8	229°30′	Mouth BW, EW, GB

[1] Abbreviations: RB = right bank, EB = edge of bank
EW = edge of water, LB = left bank
BW = backwater, GB = gravel bar.

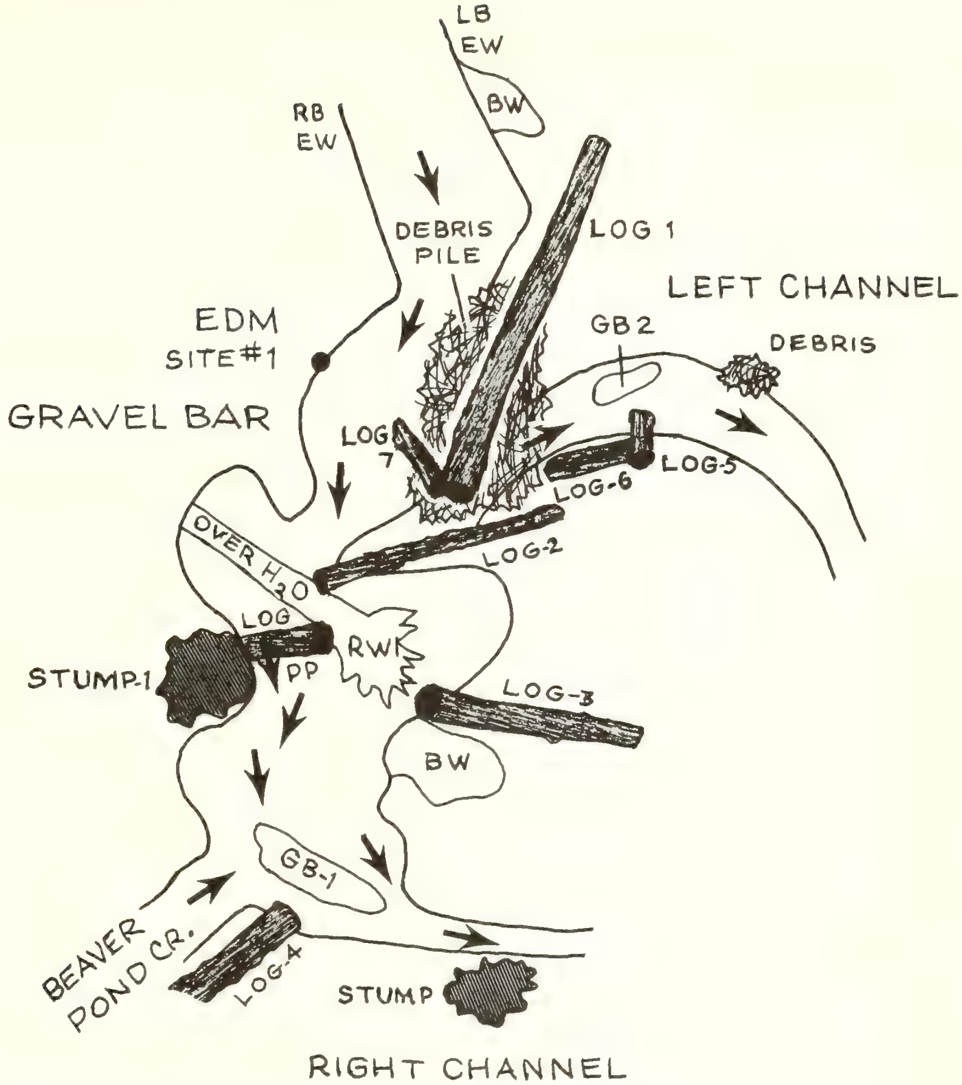


Figure 42—Sample of rough sketch and data taken during survey with an electronic distance meter (EDM).

details that are included in the final map. The differences between proportions of the rough map and the final map are significant and demonstrate the limitations of a "by eye" sketch for accurate location of points in a study area.

A less time-consuming method is to map individual pieces of debris rather than an entire reach. Individual pieces of large debris (greater than 30 cm in diameter and 2 m in length) are marked. Stanley V. Gregory of Oregon State University (personal communication) used small plastic disc tags—similar to Peterson disc tags—with individual numbers for each piece of debris. These were placed in holes of 5 to 8 cm that were bored into the side of the piece at each end and nailed to the piece. The location of each piece with respect to the bank and stream was recorded. The locations of the tags on the piece were recorded. By accurately identifying the position of the piece of debris, its relative stability in the channel can be determined as changes in position and orientation are measured over time.

Some advantages a scale map provides are (1) a graphic display of specific habitat types, (2) a measure of changes in channel morphology over time, and (3) a record of the locations of individual pieces of debris. In addition, a planimeter or digitizer can be used to derive area measurements from the map for each habitat type. For an intensive ecological study of a stream section, a detailed map of the stream and debris is indispensable (fig. 43).

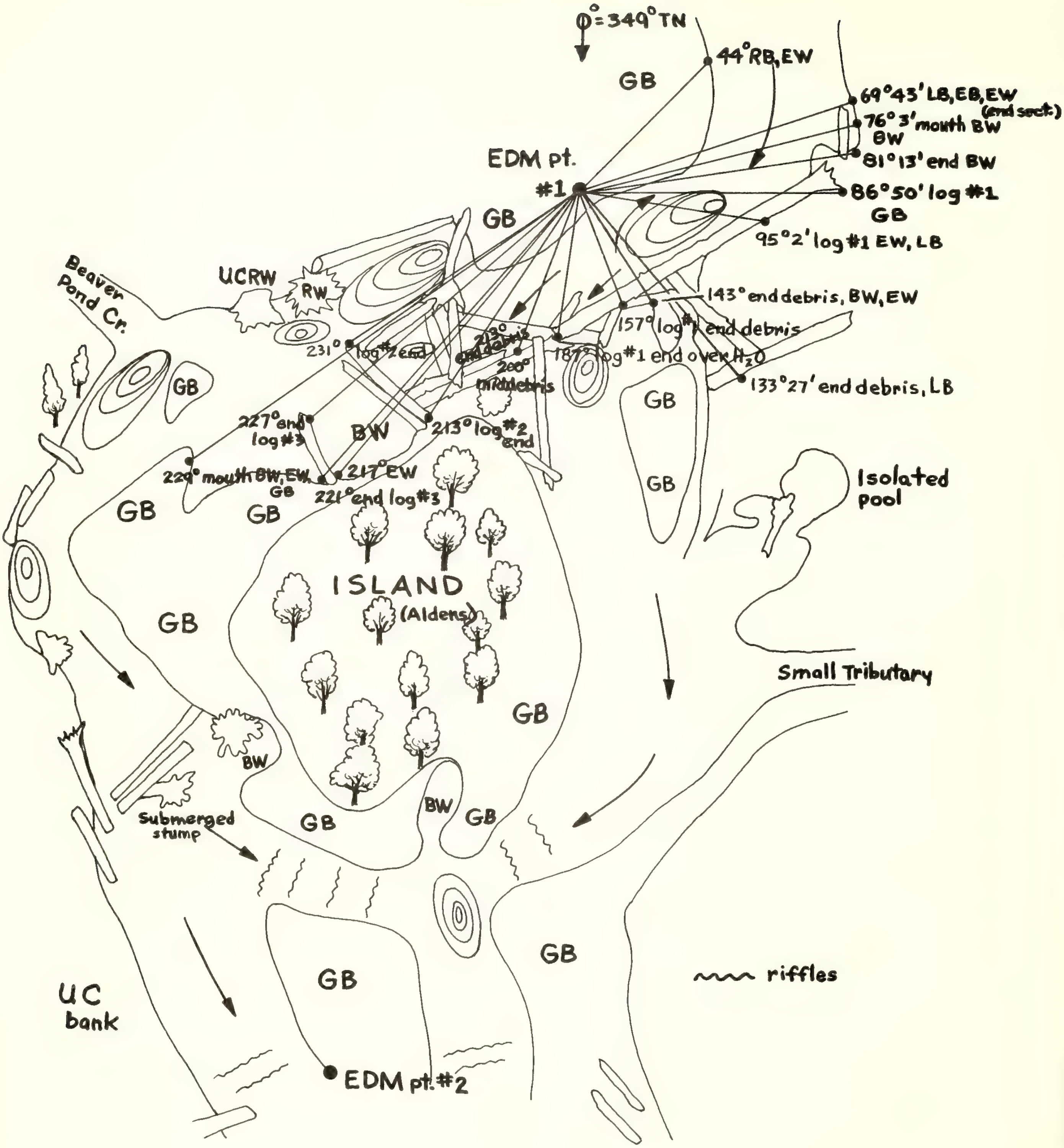

0° = 349° TN
44° RB, EW
GB
69°43' LB, EB, EW (end sect.)
76°3' mouth BW
BW
81°13' end BW
EDM pt. #1
86°50' log #1
GB
95°2' log #1 EW, LB
GB
UCRW
RW
Beaver Pond Cr.
143° end debris, BW, EW
157° log #1 end debris
231° log #2 end
213° end debris
200° middebris
187° log #1 end over H2O
133°27' end debris, LB
GB
GB
227° end log #3
BW
213° log #2 end
GB
229° mouth BW, EW, GB
217° EW
221° end log #3
GB
GB
Isolated pool
ISLAND (Aldens)
GB
Small Tributary
GB
BW
Submerged stump
GB
BW
GB
GB
GB
riffles
UC bank
EDM pt. #2

Figure 43—An example of a scale map constructed from data book entries in table 23 for Maybeso Creek.

Measuring Large Woody Debris on Stream Banks

Debris on streambanks is measured to determine the amount of material that could enter the stream channel. Measurements are made on a defined flood plain (the area outside normal flows but subject to periodic flooding). In addition, gullies, chutes, and V-notch channels leading to streams at the base of steep sideslopes may be the primary source of a large amount of organic material often in the form of debris avalanche. Measurement of woody debris in these landforms requires special consideration in methods and in the potential effect on the stream.

Measurements of woody debris along a low-gradient flood plain are made with methods similar to those used to measure debris loading in the stream channel. In the study by Swanson and others (1984) material less than 4 inches in diameter was not counted. Weight per unit area along a riparian area was estimated with the same equation given in the previous sections. A less intensive survey of LWD in a riparian area could be made by a count of individual pieces greater than 4 inches in diameter and longer than 3 ft in a defined area along the stream. Among some of the important considerations in defining potential contributions to the stream are the frequency and intensity of flooding and the size of the material. In some cases, an upper size limit could be set because the material would not be floated into the stream. In many instances, the flood plain may be a depositional area and contribute little to actual instream LWD, but the wood may be a source of nutrients or may contribute bank stability.

In measurements of this type it is important to define the flood plain area. Swanson and others (1984) used a 33-ft band on each bank for streams traversing relatively flat areas without steep banks, but the width depended on the size of the flood plain. Where the stream would not flood as great an area, as in the previous example, the width was reduced, and measurements were stopped altogether where a steep bank was encountered. Floatable debris should also be defined explicitly. Both flood plain area and floatable debris will vary with the stream system.

As already noted, steep sideslopes, gullies, and V-notches along streams are often sources of debris avalanches. The evaluation of the debris avalanche hazard is a primary consideration. Area (length and width of the gully), gradient of the slope, and the amount of debris are the primary measurements that will influence the degree of avalanche hazard. The percentage of area covered by debris can be measured by visual estimate or by counting individual pieces and by sampling the size and weight by scaling. However, in actual practice individual counts in large, steep V-notches can be an arduous task. Therefore, a relative index of sparse, moderate, or heavy loading in a V-notch will provide the most efficient method to evaluate potential avalanche sites along streams. This, combined with gradient of V-shaped area, would provide a good data base for streamside management purposes.

HISTORIC EVALUATION OF RIPARIAN HABITATS

Riparian areas constitute a small fraction of the total habitat types and ecosystems of the world, but they are some of the areas most heavily impacted by humans. Water bodies are sites of settlement and sources of water supply for people and domesticated plants and animals, and provide transportation avenues. Despite such uses and familiarity, riparian areas are one of the least understood habitats. Scientists are beginning to comprehend the importance of riparian systems, and the research effort has greatly increased in recent years, but so many changes have already occurred that few streams today still have pristine riparian areas.

While a certain amount of information may be gained by studying riparian areas as they exist at this time, a complete understanding cannot be obtained without considering their historical condition—their pristine state and the ways that humans have altered it. Because many of these alterations took place when an area was first settled, it becomes necessary to consult the historic record for information on original conditions. This chapter will examine the importance of historical research and discuss the methodology involved.

Consulting the Historical Record

Historical information regarding pristine riparian conditions can be obtained from three general sources: descriptive accounts of individual streams, records not primarily concerned with streams but including information in context with human activities, and statistical accounts compiled by State and Federal agencies.

Descriptive accounts of individual streams occur mostly in the form of State or Federal survey reports. By 1900, the U.S. Army Corps of Engineers had recorded general descriptions of most of the major waterways in the United States. Early court cases over navigable streams, riparian owner rights, and water rights sometimes contain stream descriptions. The U.S. Fish and Wildlife Service and State departments of fish and game have survey records for smaller streams, but most of this information is fairly recent (1920's to date). The majority of the earliest records of pristine stream conditions are found in records not primarily concerned with streams. These include fur trappers' and explorers' journals, pioneer diaries, letters, and memoirs. These sources require considerable sifting to obtain a few nuggets. Statistical accounts often accompanied State and Federal surveys and are frequently encountered in House and Senate documents. County, State, and Federal courthouses contain large numbers of statistical accounts.

Information can be further subdivided into primary sources, those written about events during the time they occurred, and secondary sources, those written later compiling many original accounts into a general overview. Burke (1979) notes that "the most accurate information is usually found in the original record. Primary sources, such as field notes and journals, diaries and letters, unpublished manuscripts and reports, and other archival materials allow the researcher to make judgments about the events without interpretation by anyone other than the originator of the document." Although secondary materials are presented from an author's perspective and therefore biased, they are more numerous and easier to access than primary sources and generally contain references to primary material.

A general approach to collecting historical information is to begin with general sources and become more specific in the search as the amount of information available becomes better known (Frick 1980). A good starting point is to check bibliographies and indexes for books and journal articles on the subject (see appendix 7 for a partial list). The bibliographies will suggest further reading and may indicate nonlibrary sources, such as historical museums and courthouses, for additional materials (see appendix 7). It is important during this phase of the research to maintain a working bibliography to keep track of the information gathered and to avoid duplication of effort.

Maps can be useful for tracing changes in stream courses and, in some cases, vegetation. While most of the surveying in the East was done after settlement, surveying in the West took place concomitant with or slightly before settlement, therefore giving some evidence of how pristine streams appeared. The U.S. Land Office was responsible for surveys beginning in the 1850's. The resulting records (maps and survey notes) are on file with the Bureau of Land Management, U.S. Department of the Interior. The maps themselves may be found in libraries. The U.S. Geological Survey began publishing topographic maps in the early 1900's. These are periodically updated, showing changes in stream channel configuration (fig. 44). Aerial photographs are good for documenting recent changes (1930's to present).

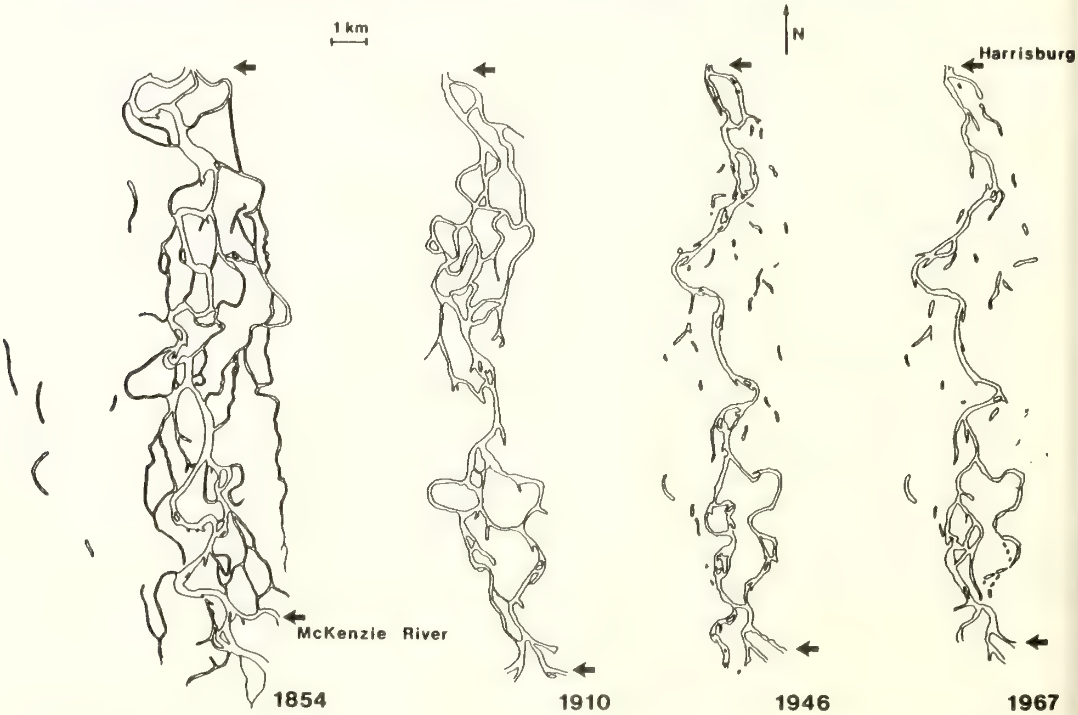


Figure 44—Changes in channel configuration over time, Willamette River, OR.

Another important source of information is early photographs. They may be of limited use in Eastern United States and Europe because most streams in those areas had been substantially altered long before the camera was invented. However, photographs of the Western United States where development was much later can be invaluable. For example, almost every historical museum in the Western United States has a photographic collection containing pictures of early logging practices, log drives, grazing, and mining activities. Photographs can show details that were incidental to the subject of the picture or details that authors of the time considered too common to note. Landscape photographs can be used in repeat photography where changes over time can be documented by repeatedly photographing an area from the same vantage point over the course of many years (Hastings and Turner 1965; Trefethen 1976; Gruell 1980).

Interpreting the Records

Just because a document is old and faded or published in 1884 does not mean that everything it says is true. There is a tendency on the part of nonhistorians to accept old documents at face value, forgetting that those early writers were as fallible and biased as the modern writers we critique so carefully today. It is therefore necessary to carefully evaluate historical documents before accepting their contents wholeheartedly (Forman and Russell 1983).

Two critiques should be used when evaluating historical material (Shafer 1980). The first, external criticism, helps to establish the authenticity of the document itself. This can be done by analyzing the contents for anachronisms, comparing the contents with other evidence outside the document, and testing the physical properties of the document itself. External criticism is important in determining the authenticity of ancient manuscripts such as the Dead Sea Scrolls and in exposing hoaxes such as the more recent Hitler diaries.

The second, internal criticism, helps to determine the credibility, meaning, and value of the document. Primary authors must observe a situation, report on it, and have a reason for doing so, and their motivation will influence how they treat their observations. An army doctor stationed in a marshy bottomland may report many cases of malaria; a land speculator encouraging people to settle the same bottomland will report that malaria is practically nonexistent. Secondary authors carry their personal philosophies and values to their work, and they affect the search for evidence and the interpretation of that evidence. Internal criticism, therefore, focuses on the author and his or her ability to observe and report, and on the intent of the composition. It also takes into consideration such factors as the amount of time that passed between the event and when it was recorded. Shafer (1980) is a good guide to external and internal criticism and their use in evaluating historical documents.

Problems in Interpretation

Most historical documents containing descriptions of riparian conditions did not have riparian areas as their primary subjects but rather contained only comments on them in passing. It is important to consider authors' reasons for writing their primary subjects, their ability to report observations, and what preconceptions and biases influenced them. Without taking these factors into consideration, it is easy for modern historical researchers to use historical material to support any conclusions they choose.

Hastings (1959) gives special attention to two of the many pitfalls in historical research that particularly apply to evaluating ecological change. He first quotes two examples of early descriptions of Arizona. The first is from an account by James H. Tevis, who came to Arizona in the 1850's. In those days, it should be remembered, grass grew very tall, belly-high to a horse. Tevis compares these conditions with those 50 years still earlier, as described to him by an Indian.

> In those days the grass grew very tall...in fact, so tall that one could see only the heads of antelopes (Tevis 1954).

The second is by Col. Green, Commandant of Camp Apache, Arizona Territory, writing in 1871:

> If you wish any further correspondence from me as to my views of Arizona, I can only tell you I have been over a great portion of it...and found it a rocky, mountainous desert, not fit even for the beasts of the field to live in (**Citizen**, April 22, 1871).

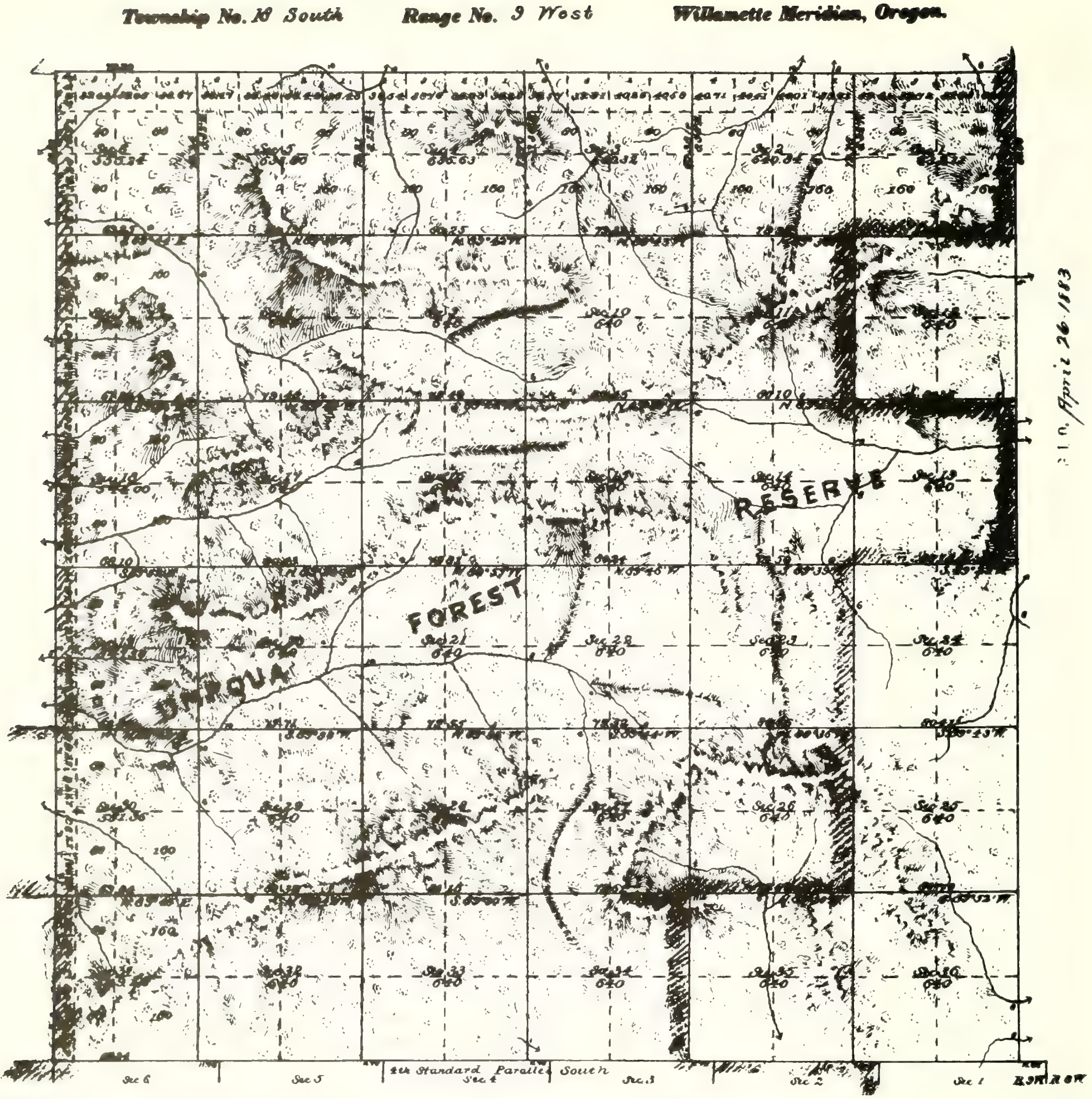
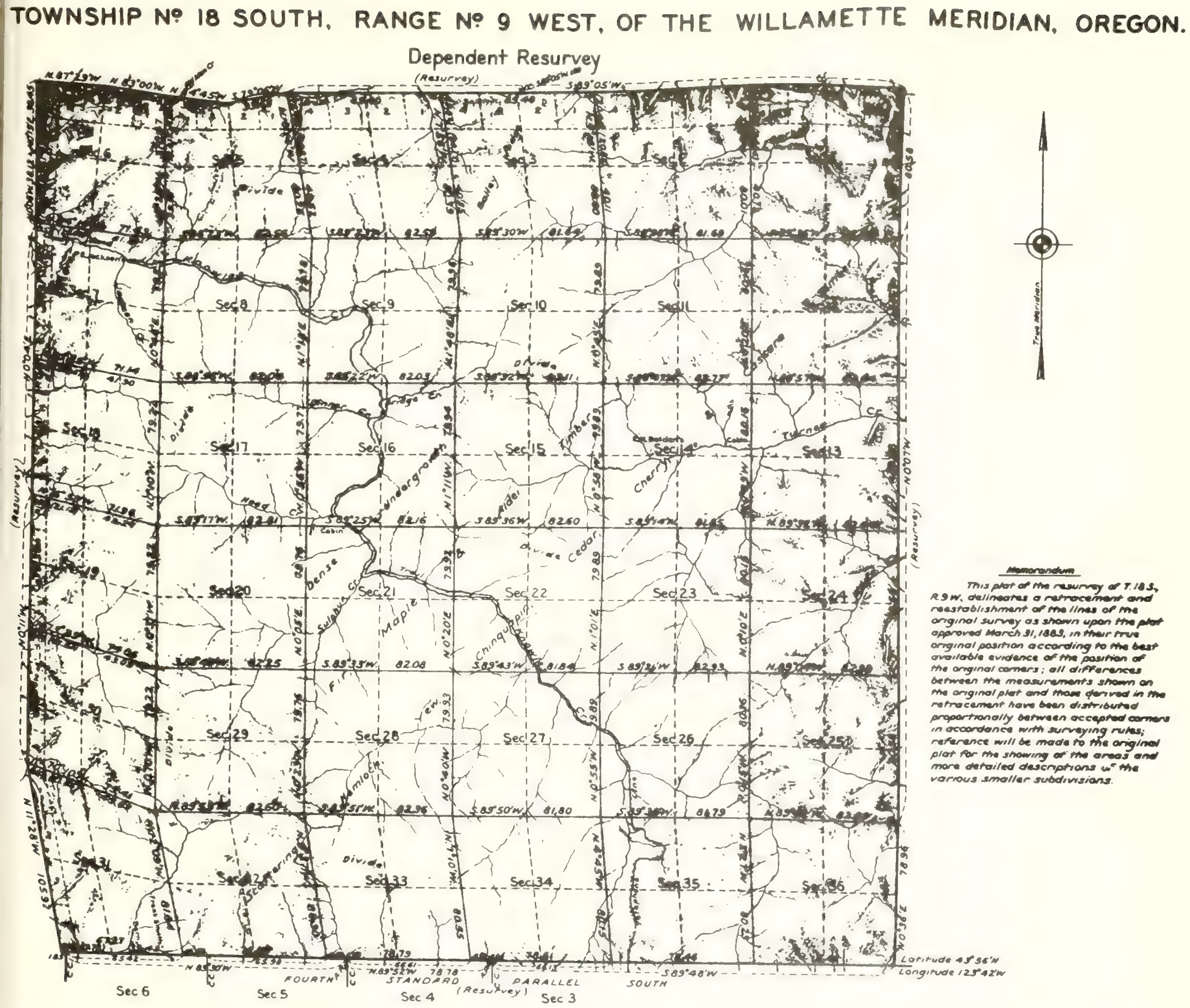

Township No. 18 South
Range No. 9 West
Willamette Meridian, Oregon.
UMPQUA
FOREST
RESERVE
Sec. 21
Sec. 22
Sec. 23
Sec. 24
Sec. 26
Sec. 25
Sec. 33
Sec. 34
Sec. 35
Sec. 36
4th Standard Parallel South
April 26 1883

Figure 45—Survey of same section of Knowles Creek on the Oregon Coast, OR, in (A) 1882 and again in (B) 1929 showing major discrepancies between surveys. The 1929 resurvey is accurate. (Courtesy of Bureau of Land Management.)

(A)

Hastings then goes on to describe the two pitfalls:

> The first is the "good old days" fallacy. This longing after another time, another place, is implicit in much of human thinking; it operates particularly insidiously in the field of historical reminiscence. It colors the conclusions drawn from such materials unless the researcher exercises caution. To us the golden age of Arizona ecologically lay in Tevis' time. To Tevis, in turn, it lay fifty years still earlier, during the childhood of his friend the Indian Esconolea. To Esconolea's grandfather? The golden age retreats inexorable with each generation.
>
> A second pitfall is implied in the consideration that Colonel Green wrote in disparaging terms about conditions which were very good indeed according


TOWNSHIP No 18 SOUTH, RANGE No 9 WEST, OF THE WILLAMETTE MERIDIAN, OREGON.
Dependent Resurvey
(Resurvey)
Sec 8
Sec 9
Sec 10
Sec 11
Sec 13
Sec 14
Sec 15
Sec 16
Sec 17
Sec 18
Sec 20
Sec 21
Sec 22
Sec 23
Sec 24
Sec 25
Sec 26
Sec 27
Sec 28
Sec 29
Sec 31
Sec 32
Sec 33
Sec 34
Sec 35
Sec 36
Divide
Cabin
Dense
Fir
Maple
Cedar
Timber
Undergrowth
Chinquapin
Cherry
Hemlock
True Meridian
Latitude 43°56'N
Longitude 123°42'W
FOURTH STANDARD PARALLEL SOUTH
(Resurvey)
Sec 6
Sec 5
Sec 4
Sec 3

Memorandum

This plat of the resurvey of T.18 S., R.9 W., delineates a retracement and reestablishment of the lines of the original survey as shown upon the plat approved March 31, 1883, in their true original position according to the best available evidence of the position of the original corners; all differences between the measurements shown on the original plat and those derived in the retracement have been distributed proportionally between accepted corners in accordance with surveying rules; reference will be made to the original plat for the showing of the areas and more detailed descriptions of the various smaller subdivisions.

Figure 45 (Con.) **(B)**

to the Arizona legend. The legend does not necessarily err. It, after all, takes the same spatial area and compares it at two points in time. Green, on the other hand, compares two different areas in space at the same point in time.

To him the Arizona of a century ago seemed uninhabitable because he tended to think of it in terms of Massachusetts, or Virginia, or Ohio. Compared to those well-watered regions of the same day, Arizona was not a "Land of Milk and Honey" at all; it was a howling, arid wilderness.

Maps present another set of problems in interpretation. Those drawn by early explorers are generally unreliable because the authors did not personally see everything they included. The surveys done by the U.S. Land Office for some areas are quite accurate and detailed, although details do not necessarily mean accuracy. For other areas, the map is so different from what exists today that there is some suspicion that the surveyor never set eyes on the territory (fig. 45). The U.S. Geological Survey topographic maps are accurate but cover a later period after most of the changes to streams and riparian areas had already taken place, and aerial photographs are still later.

Using the Historical Record

Perhaps the best way to better understand the type of information available from the historical record, and how to use it, is to examine case studies. Some human activities that have impacted streams and riparian systems include farming, grazing, mining, logging, and transportation. Different historical sources provide valuable information for these different categories.

Farming—Flood plains are well known for their fertile soil, making them prime targets for settlement. Farmers not only cleared riparian land for crops but also used timber for homes, barns, fences, and firewood. This impact was restricted and localized by topography in some areas. In others, such as the Willamette Valley in Oregon, over 193 miles (65 percent) of the river was impacted.

While specific data on riparian clearing is unavailable, we can still trace the pattern of its demise in the Willamette Valley from various historical sources (Sedell and Froggatt 1984). The Willamette Valley was characterized by a prairie-open woodland vegetative complex maintained by fires set by Indians, with trees either on steeper slopes or in the riparian area (Towle 1974). The riparian woodland was 0.9 to 2.2 miles wide on either side of the river (Towle 1974) and was bisected by many small tributaries, channels, and sloughs that frequently overflowed (Williams 1914). Flooding was a major concern for the first settlers in the late 1840's who immigrated from the flood-prone Midwest and initially settled on lands away from the river (Bowen 1972). By 1870, Oregon's population had increased almost sevenfold over the 1850 population, 80 percent of the people lived in the Willamette Valley, and the bottomlands were rapidly settled (Dicken and Dicken 1979). With increased agricultural activity came urban centers along the river, the main transportation route of the valley. The settlers harvested easily accessible wood from the flood plain. By 1900 most of the good land in the valley was occupied; by 1930 it was not only occupied but cultivated. The net impact on the riparian woodland is seen in figure 46. A similar scenario developed along the Sacramento River in California (Sands and Howe 1977) and along the Colorado River (Ohmart and others 1977).

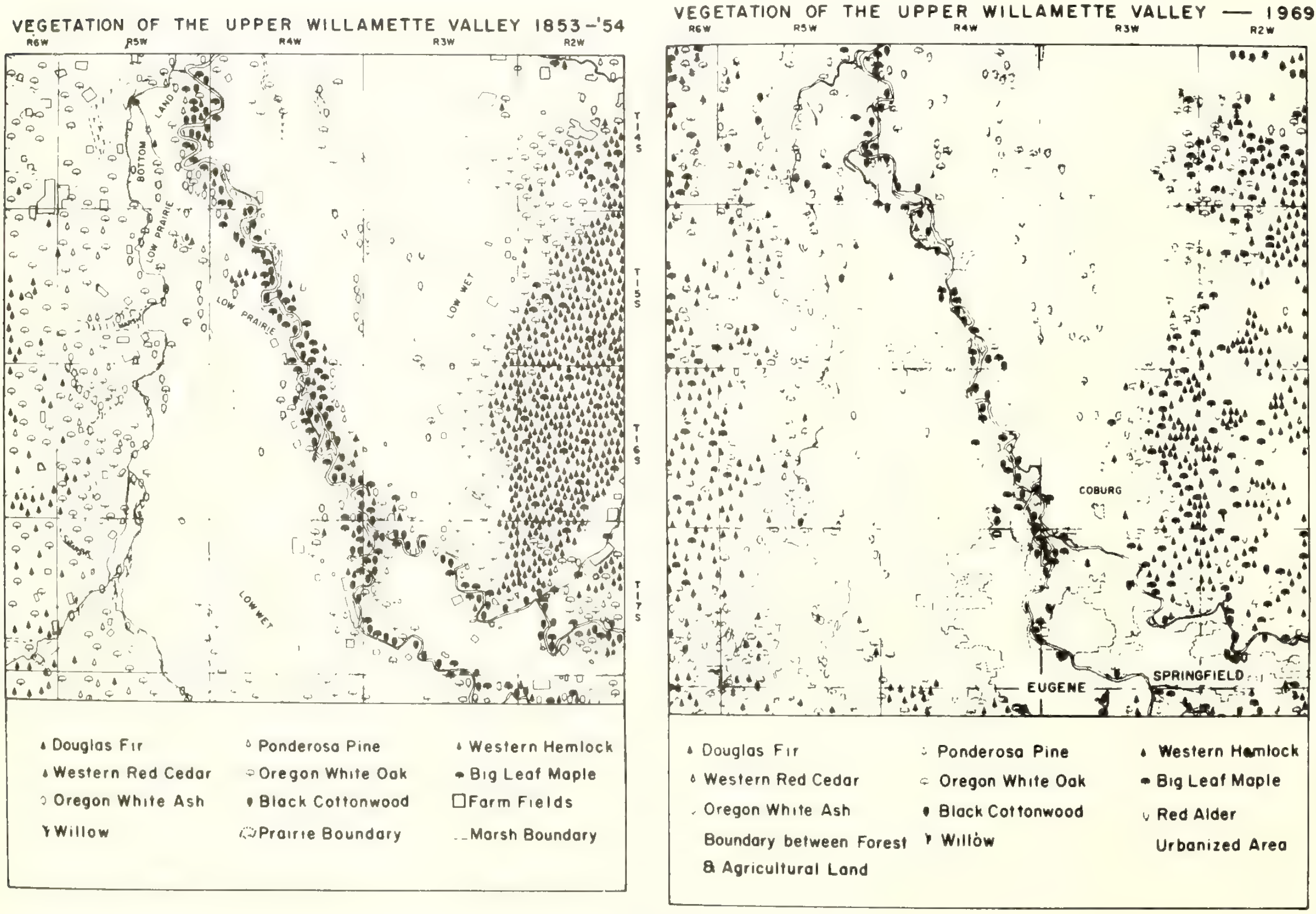

VEGETATION OF THE UPPER WILLAMETTE VALLEY 1853-'54
R6W
R5W
R4W
R3W
R2W
T14S
T15S
T16S
T17S
BOTTOM LAND
LOW PRAIRIE
LOW PRAIRIE
LOW WET
LOW WET
Douglas Fir
Western Red Cedar
Oregon White Ash
Willow
Ponderosa Pine
Oregon White Oak
Black Cottonwood
Prairie Boundary
Western Hemlock
Big Leaf Maple
Farm Fields
Marsh Boundary
VEGETATION OF THE UPPER WILLAMETTE VALLEY — 1969
R6W
R5W
R4W
R3W
R2W
T14S
T15S
T16S
T17S
COBURG
EUGENE
SPRINGFIELD
Douglas Fir
Western Red Cedar
Oregon White Ash
Boundary between Forest & Agricultural Land
Ponderosa Pine
Oregon White Oak
Black Cottonwood
Willow
Western Hemlock
Big Leaf Maple
Red Alder
Urbanized Area

Figure 46—Vegetational changes along the Willamette River, OR (from Johannessen and others 1970).

Grazing—Livestock arrived with the first settlers but only in small numbers to serve as work animals or as a food source to the local community. Well-watered land was quickly converted to crops leaving the more arid land for "the only thing it was good for"...grazing.

The era of huge herds and massive drives was established after buffalo and Indians were no longer occupying the grasslands and before farmers had the technology to fence, irrigate, and plow the range. The free forage on the open grassland, markets in the mining, railroad, and military camps, and later the rail connection to markets in the East meant a quick profit for ranchers who rapidly filled the range with cattle and sheep. By 1879, some of the range, especially in Colorado, was being overgrazed, but the next 7 years saw large increases in the number of livestock and cattle companies, and the range became overcrowded (Frink and others 1956). Severe winters, dry summers, and low market values from 1885 to 1886 caused many cattle companies in the Great Plains to fold, and the cattle industry was reorganized into smaller herds that no longer depended solely on open rangeland for forage. Arizona's cattle population went from 5,000 head in 1870 to 35,000 in 1880 to 1,095,000 in 1890 before the drought of 1891 to 1893 reduced the herds by 50 percent (Hastings and Turner 1965). By the turn of the century, farmers were making inroads on settling and cultivating the grasslands, and livestock were no longer free to roam.

Frink and others (1956) noted that: "By preempting land near water, a man could shut others out and so have the use of great grazing areas that were in the public domain but that others could not use because they had no access to water." Later, when the cattlemen realized they could not feed livestock only from the range, the riparian wetlands were converted to hayfields (Griffiths 1902, 1903).

Grazing impacts on riparian areas have been the focus of many investigations (Platts 1981a; Kauffman and Krueger 1984). While damage continues, much of it was already done by 1900 (fig. 47).

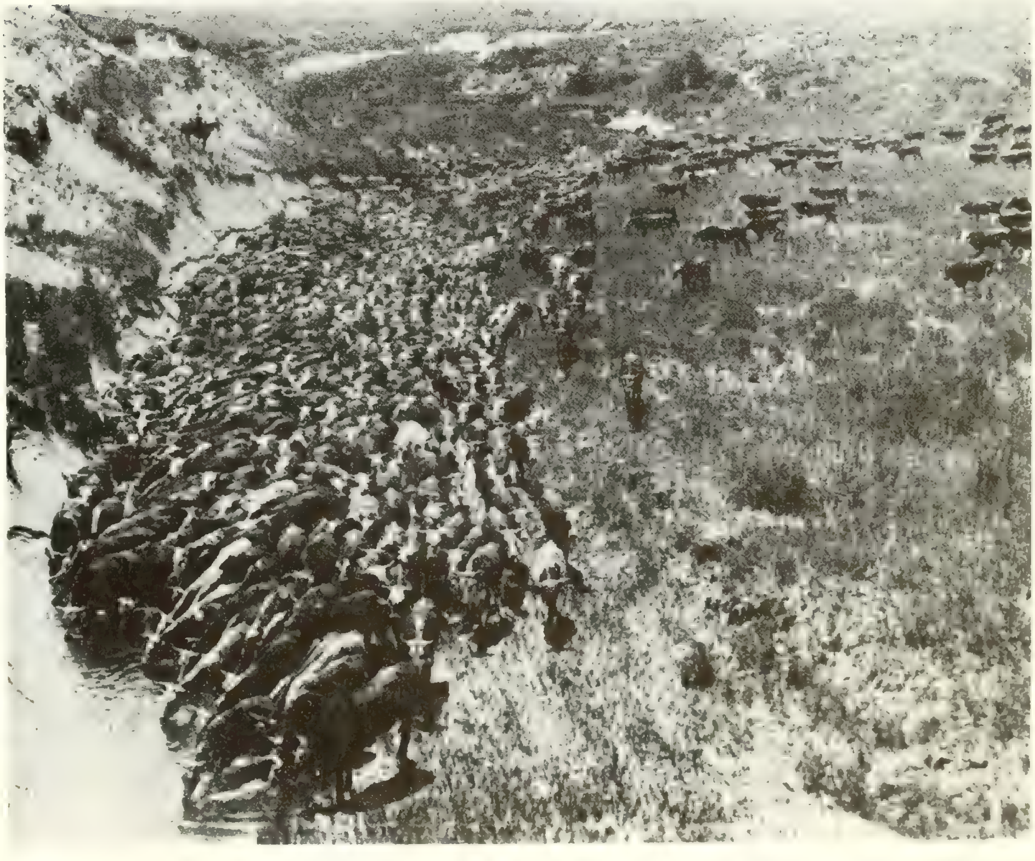


Figure 47—A Texas trail herd reaches water, 1890's (William H. Jackson photo, from State Historical Society of Colorado).

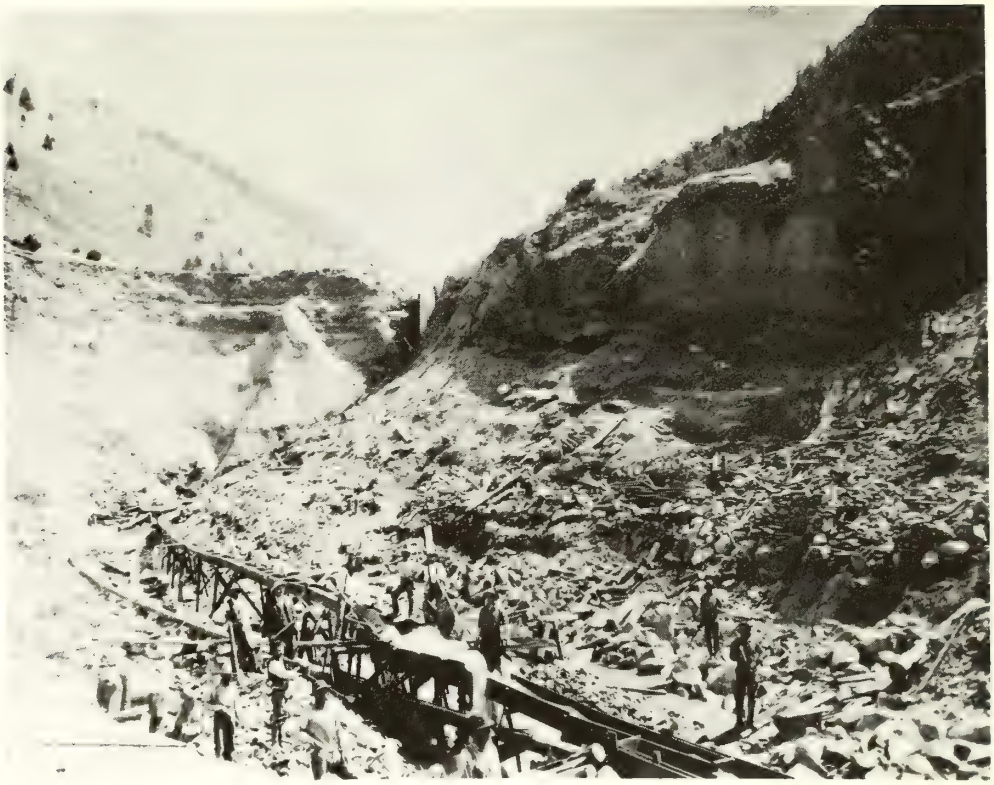


Figure 48—Placer mining in Confederate Gulch near Helena, MT, 1860's (Historical Photography Collection, University of Washington Libraries).

Mining—The first impact usually associated with mining operations is in-stream pollution from tailings. Water was often used to wash and sift ore, and whole streams could be diverted to this purpose (fig. 48). This would affect the water flow downstream causing some creeks to go intermittently or totally dry. The tailings were sources of sediment and at times toxic substances that would adversely affect in-stream flora and fauna.

In addition to their impact on streams, mining operations severely impacted riparian vegetation, particularly trees. In western Nevada from 1853 to 1914, over 64 sawmills operated on sections that are now relatively treeless. Billions of board feet of timber were driven down the Truckee, Carson, and Walker River systems for lumber, firewood, and other uses related to the development of the silver mines around Virginia City (Anonymous 1941). Many of the mining and smelting activities in Arizona, Montana, Utah, and Colorado in the late 1880's depended on stream transportation of logs. In these arid climates, where timber was not abundant, denudation occurred quickly (fig. 49).

Logging—Numerous books have described the history of the timber industry, and many articles have glorified log drives on rivers. But only one significant book—by Rector (1953)—has been published on the extent and role that water transportation played in the early days of the timber industry. A book-length manuscript by James Farnell (unpublished) was produced from research undertaken for the State Lands Division of Oregon, in which the extent of navigation was determined for each of Oregon's river basins. Each of the 23 basin studies was issued as a navigability report from the State Lands Division in Salem. These two documents record the extent, duration, and dependence on water for log transportation. The changes to stream habitats and streamside vegetation have been documented by Sedell and Luchessa (1982) and Sedell and Duval (1985).

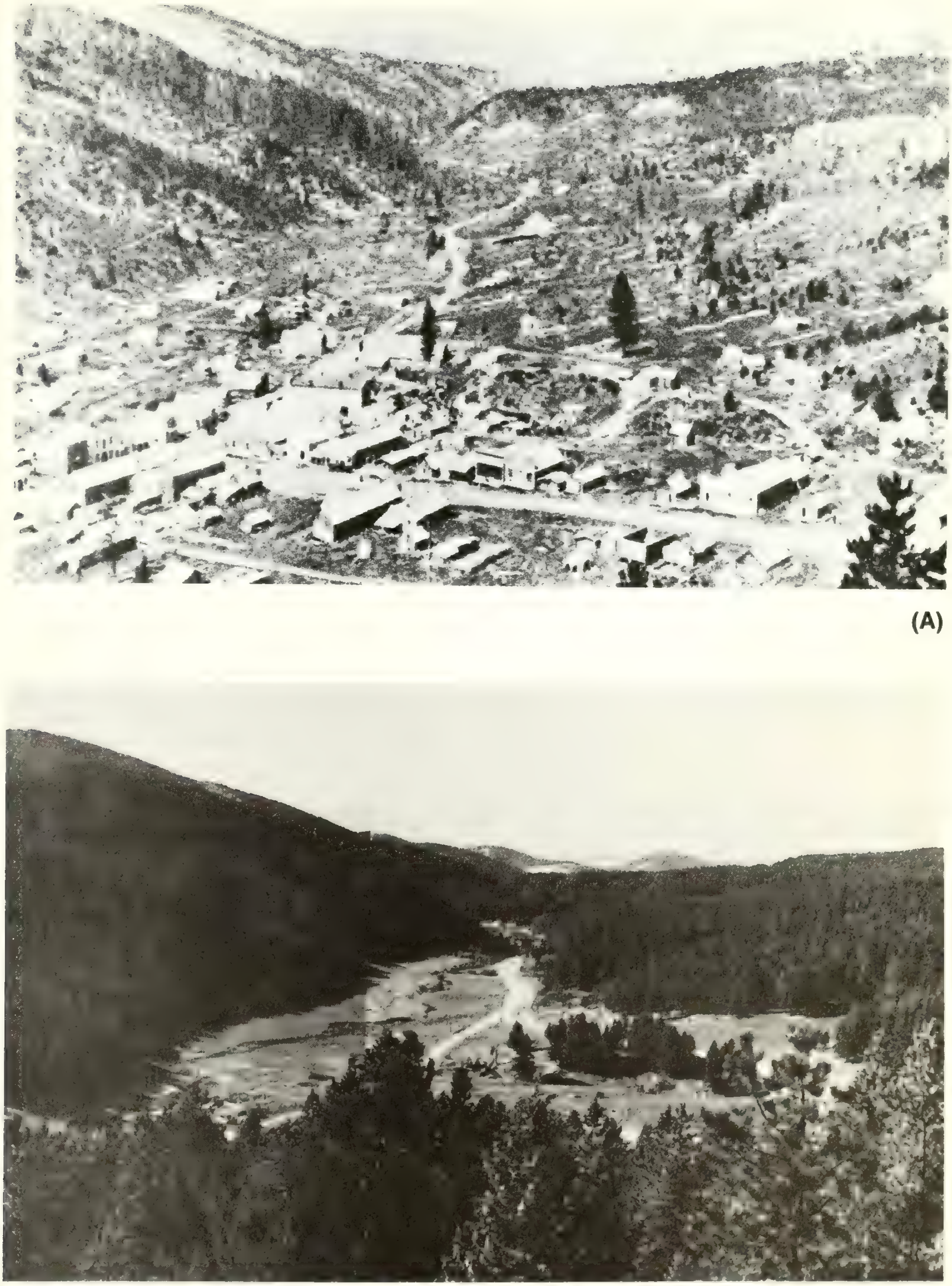


Figure 49—Maiden Canyon in Montana's Judith Mountains. (A) In 1892: the area has been stripped of timber to provide fuel and prop supports for mining in the area (photo, W. H. Weed, U.S. Geological Survey). (B) In 1964: little of the mining town remains, and the area is largely reforested.

By the early 1880's, the best timber within 2 miles of the entire shoreline of Hood Canal, a section of Puget Sound, had been cut (Buchanan 1936). The same was true of most other readily accessible areas. Loggers constantly sought out streams along which the timber had not yet been cut. If a stream was large enough to float logs, it was soon in use. A newspaper, The West Shore, announced in 1883 that in Columbia County, OR, every "stream of any size has been cleared of obstructions, so that logs can be run down them in the high water season" (Anonymous 1883). By the end of the 1880's the same was true of almost any county along the lower Columbia, around Puget Sound, or along the "lumber coast" (Cox 1974).

From earliest days, stream improvement for log transportation encountered legal difficulties. To keep mill owners and farmers from blocking the rivers with dams and other obstructions, a stream had to be declared navigable. In Michigan, Wisconsin, and Minnesota, the courts decided that a stream that could float a sawlog was a "public highway" and that sawlogs had just as much right to be on the rivers as rafts, barges, and steamboats. Navigable streams were not to be blocked by bridges, piers, fences, or ponds. At the same time, lumbermen were not to build storage and splash dams without special legislative permission (Rector 1953).

The U.S. Government transferred ownership of the beds of the navigable waterways to a State when it entered the Union. To ascertain which riverbeds were transferable, the U.S. Supreme Court defined a navigable river:

> Those rivers must be regarded as public navigable rivers in law which are navigable in fact. And they are navigable in fact when they are used, or susceptible of being used, in their ordinary condition, as highways for commerce, over which trade and travel are or may be conducted in the customary modes of trade and travel on water. (The Daniel Ball, 1870).

All of the Western States must in general comply with this definition of navigable waters.

In Washington, any stream that was capable of successfully floating logs was a floatable stream, and the logger had a right to use its waters to float logs toward the mill or market. Even though a stream was completely incapable of such log floating during the dry season, its waters were public if natural freshets provided enough water to float logs. Thus, the logger had no right, over the objections of the riparian owner, to put in roll dams to cause backwaters or splash dams to create artificial freshets. The boom and driving companies were able to obtain the right to drive a floatable stream because they were quasi-public corporations (Bridges 1910). As such, they had the power of eminent domain and could run their splash dams by condemning the property and paying in advance to every landholder adjoining the stream.

Even though litigation frequently resulted, most streams in western Oregon and Washington were used for log drives.

Log driving is simply the process of transporting logs by floating them in loose aggregations in water with the motive power supplied by the natural or flushed streamflow (fig. 50). At first, all timber within easy access of the stream was cut and floated down the adjacent river. If timber was too far away to be profitably hauled by oxen to the mill or stream, the logger moved to another location. Gradually, loggers had to go greater distances for timber, which introduced the use of river landings, log yards, log driving, rafting, towing, and booming (Rector 1949). Still later, the more distant timber required the use of splash dams and sluiceways, expensive stream improvements, canals, tramways, trestles, log chutes and slides, trucks, and railroads for floating and driving.

As more logs were needed, artificial freshets were created by splash dams. A splash dam was a device for turning tiny streams into torrents large enough to float logs (fig. 51). A dam would be built on a stream and water stored behind it. When a large head of water had been accumulated, it would be released and would quickly sluice logs that had been dumped into the pond behind the dam—together with others collected along the watercourse below the dam—to where they could be handled by conventional means.

Streams of all sizes had to be "improved" before a log drive could begin. Principal forms of stream improvement were (Brown 1936):

> Blocking off sloughs, swamps, low meadows, and banks along wider parts of the streams by log cribbing to keep the logs and water in the main stream channel.

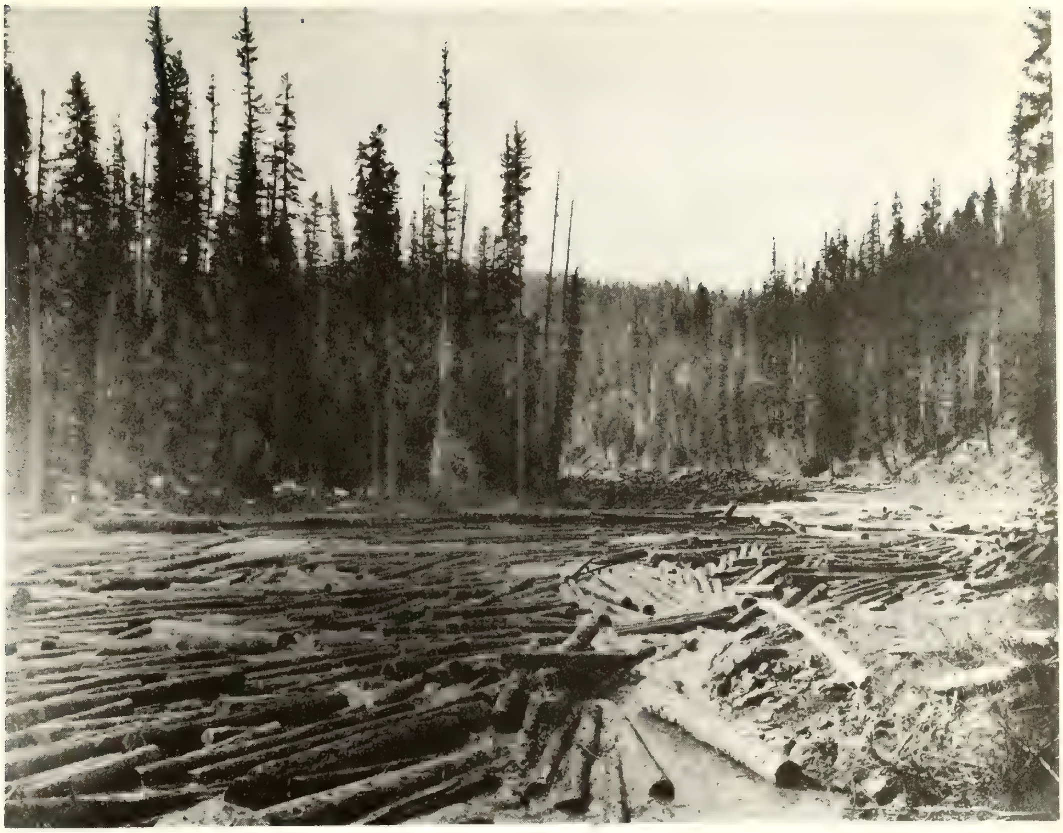


Figure 50—Log drive on the St. Joe River, ID (Eastern Washington State Historical Society).

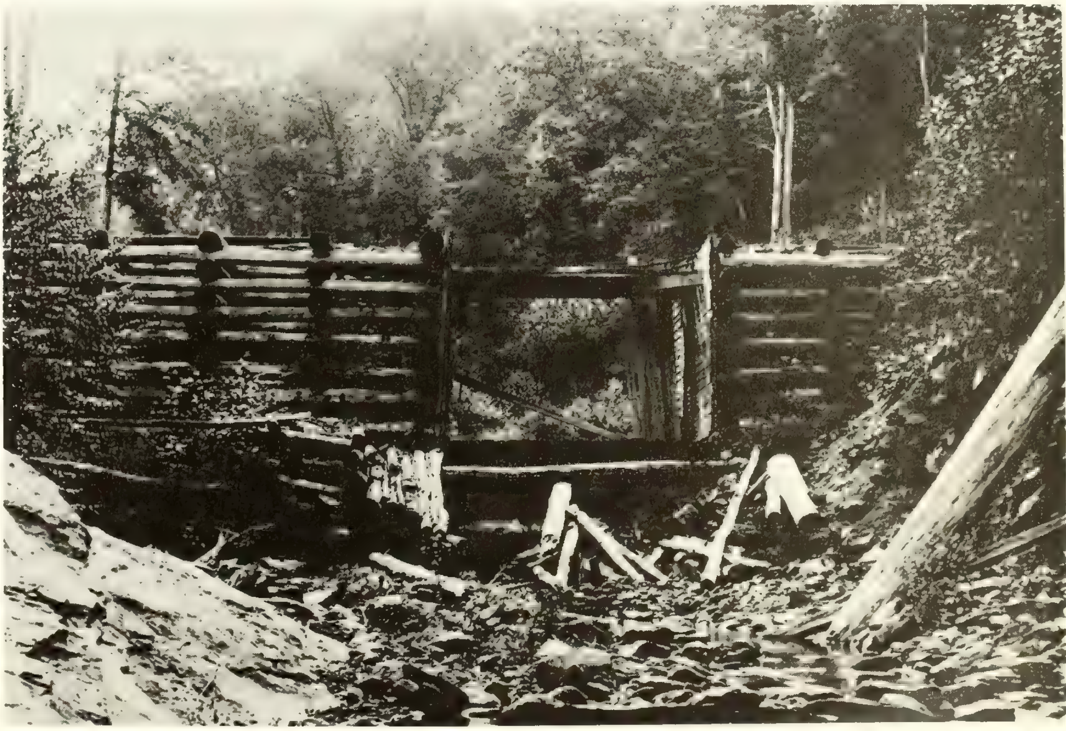


Figure 51—Splash dam on Bob Creek.

> Blasting out or removing boulders, large rocks, leaning trees, sunken logs, or obstructions of any kind in the main bed during periods of low flows. Obstructions or accumulations of debris—such as floating trees, brush, and rocks—often caused serious and expensive log jams during the driving seasons. Frequently, small, low-gradient streams were substantially widened during log driving, as a result of the frequent flushing of the stream by splash dams and by the impact of the logs along the streambank.

By 1900, over 130 incorporated companies for river and stream improvement were operating in Washington. The distribution of major splash dams in western Washington and western Oregon is well documented by Sedell and Duval (1985). Over 150 major dams existed in coastal Washington rivers, and over 160 splash dams were used on coastal and Columbia River tributaries in Oregon. The splash dams shown by Sedell and Duval (1985) represent only the main dams that operated for several seasons. On many smaller tributaries, temporary dams were used seasonally, but no records were kept. Wendler and Deschamps (1955) were mainly concerned with these dams as obstacles to fish migration. Many were actually barriers, but the long-term damage was probably caused by the stream improvement before the drive and the scouring, widening, and unloading of main-channel gravels during the drive.

The rivers in the more arid parts of the United States also had to be improved before log drives could begin. Marble Creek on the St. Joe River in Idaho is one example. Blake (1971) described the numerous debris jams that had been there for many years. In an 18-mile stretch ending at Homestead Creek, over 500,000 board feet of good timber were recovered from the stream channel. An additional large amount of wood was used to fuel the steam donkey's trip up the canyon to Homestead Creek. Blake and his companions also "...pulled over and sawed any trees standing on the bank which might fall and cause a jam while the drive was on" (p. 73). Fishing was described as excellent on this stream before the drives. "Fifteen minutes after we moved through a deep hole, we could catch 6 or 8 large trout there. I have never seen trout fishing, from Canada to California, half as good as the fishing on the Marble Creek before the log drives" (p. 73). This is probably a "fish story" to some extent, but the fact remains that large trout were not there after the log drives.

Transportation—In addition to the stream clearing done to facilitate log drives, much cleaning was done for navigational purposes, maintaining open channels for boat and barge passage. Rivers were the main arteries of transportation until railroads and automobiles (highways) replaced them. In 50 years, over 800,000 snags were pulled from the lower 1,000 miles of the Mississippi River. Most of these were sycamore and cottonwood snags averaging 5.5 ft in diameter at the base, 2.3 ft at the top, and 115 ft in length (Sedell and others 1982). Over 65,000 snags and streamside trees were pulled and cut along the Willamette River from 1870 to 1950 (Sedell and Froggatt 1984). The U.S. Army Corps of Engineers has a long history, from the 1870's to the present, and some good records of "maintaining waterways free of obstructions." The Annual Reports put out by the Chief of Engineers of the U.S. Army (Secretary of War 1915) contains information on surveys done to determine the necessity of stream improvement, the various stream improvement activities performed (such as snagging, dredging, building of wing dams), and records of commerce. Stream cleaning was also done by State and local governments or private corporations, but there are fewer records of their activities.

The steamships for whom the rivers were cleaned had another impact on the riparian forest. They burned about four cords of wood per hour, 10 to 13 cords of wood per day (Williams 1980; Sedell and Froggatt 1984), and the closest available fuel grew along the stream. Along the Colorado River, fuel stations were located at 25-mile intervals, and such was the demand that the Indians became profitable woodcutters (Ohmart and others 1977). Woodcutting for the steamships was a major source of income for people in the Columbia River Gorge area (Williams 1980). The steamship era lasted for 60 years (1850 to 1910), but by 1910 the majority of the wood had already been removed from the streams and streambanks (Sedell and others 1982).

The demise of the steamships came about as the railroads came into use, and the railroads had their own impacts on riparian areas. The transcontinental railroads required large and continual supplies of railroad ties, which were not preserved with creosote in those days (fig. 52). The demand was met by logging watersheds adjacent to the railway

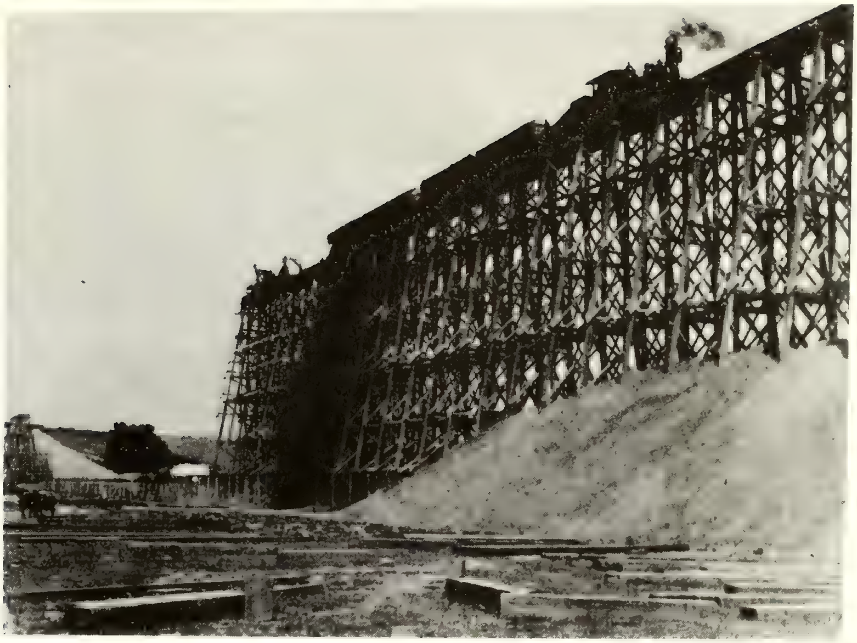


Figure 52—Construction work for large fill, Lane cut-off on the Union Pacific, 1867 (Historical Photography Collection, University of Washington Libraries).

and driving the logs down streams that intersected the line (Brown 1936). The route itself was often laid out to follow low-gradient river valleys and required removal of the riparian vegetation to accommodate it.

Implications to Riparian Research

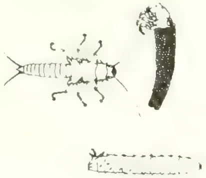
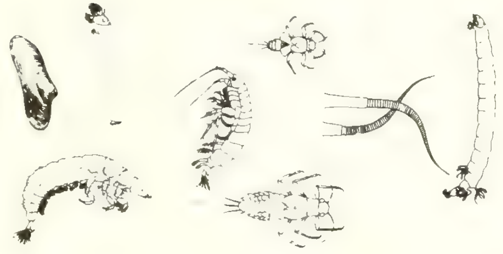
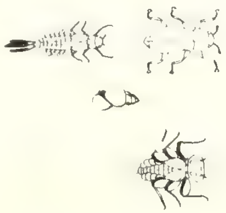
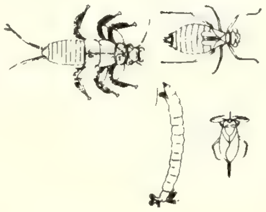
These examples demonstrate some of the substantial alterations that have occurred to riparian areas during historical times. Researchers will benefit from reviewing the historical record during their studies, even though the record may be patchy, as it will provide them with an understanding of the pristine stream condition and clarify objectives and goals of riparian enhancement and rehabilitation.

EVALUATION OF STREAM RIPARIAN AREA CONDITIONS USING BENTHIC MACROINVERTEBRATES

Historically, the composition and status of stream bottom-dwelling (benthic) invertebrates have been assessed on the basis of the taxonomic affiliation of the animals involved. Partly this individualistic, autecological approach stems from the view of the species as the basic unit of ecology, and partly it is an artifact of the historical development of knowledge in this area. In the past decade, a number of important advances in the ways that lotic ecosystems are viewed and studied have occurred (Minshall and others 1985). These have included the development of an alternative method for analyzing benthic invertebrate communities—that is, the functional feeding group approach (Cummins 1973, 1974; Cummins and Merritt 1984). This procedure permits the organization of species or higher taxa (genera, families, orders, and so forth) into ecologically meaningful groupings or guilds. The functional feeding group approach provides an assessment of the degree to which the invertebrates of a stream section/reach are dependent upon a particular food resource (table 24).

Classification of invertebrates according to feeding function is centered on morphological and behavioral mechanisms of food acquisition (Cummins 1973; Cummins and Merritt 1984). Currently, four major categories are recognized based on size, type, and general location of food ingested (table 24) (Cummins and Merritt 1984).

Table 24—A general classification system for aquatic invertebrate trophic categories (after Cummins 1973)

General category based on feeding mechanism	General particle size range of food	Subdivision based on feeding mechanisms	Subdivision based on dominant food	North American aquatic invertebrate taxa containing predominant examples
SHREDDERS 	*Microns* $>10^3$	Chewers and miners	Herbivores, living vascular plant tissue	Trichoptera (Phryganeidae, Leptoceridae) Lepidoptera Coleoptera (Chrysomelidae) Diptera (Chironomidae, Ephydridae)
		Chewers, miners, and gougers	Detritivores (large particle detritivores): decomposing vascular plant tissue; wood	Plecoptera (Filipalpia) Trichoptera (Limnephilidae, Lepidostomatidae) Diptera (Tipuiidae, Chironomidae)
COLLECTORS 	$<10^3$	Filter or suspension feeders	Herbivore-detritivores: living algal cells, decomposing organic matter	Pelecypoda Ephemeroptera (Siphlonuridae) Trichoptera (Philopotamidae, Psychomylidae, Hydropsychidae, Brachycentridae) Lepidoptera Diptera (Simuliidae, Chironomidae, Culicidae)
		Sediment or deposit (surface) feeders	Detritivores (fine particle detritivores): decomposing organic matter	Oligochaeta Amphipoda Ephemeroptera (Caenidae, Ephemeridae, Ephemerellidae, Leptophlebiidae) Trichoptera (Glossosomatidae, Helicopsychidae, Molannidae, Odontoceridae, Goerinae) Lepidoptera Coleoptera (Corixidae, Elmidae, Psephenidae) Diptera (Chironomidae, Tabanidae)
SCRAPERS 	$<10^3$	Mineral scrapers	Herbivores: algae and associated material (periphyton)	Gastropoda Ephemeroptera (Heptageniidae, Baetidae, Ephemerellidae) Trichoptera (Glossosomatidae, Helicopsychidae, Molannidae, Odontoceridae, Goerinae) Lepidoptera Coleoptera (Elmidae, Psephenidae) Diptera (Chironomidae)
		Organic scrapers	Herbivores: algae and associated material (periphyton)	Ephemeroptera (Caenidae, Leptophlebiidae, Heptageniidae, Baetidae) Hemiptera (Corixidae) Trichoptera (Leptoceridae) Diptera (Chironomidae)
PREDATORS 	$>10^3$	Engulfers	Carnivores: whole animals (or parts)	Hirudinea Odonata Plecoptera (Setipalpia) Megaloptera Trichoptera (Rhyacophillidae, Polycentropidae, Hydropsychidae) Coleoptera (Dytiscidae, Gyrinnidae) Diptera (Ceratopogonidae, Chironomidae)
		Piercers	Carnivores: cell and tissue fluids	Turbellaria Hemiptera (Belastomatidae, Nepidae, Notonectidae, Naucoridae) Diptera (Rhagionidae)

The first category, **SHREDDERS**, feed on whole or large pieces (0.04 inch across or larger) of plants, primarily by chewing. Coarse particulate terrestrial detritus is a principal food resource; living vascular hydrophyte tissue and wood are used to a lesser extent.

COLLECTORS consume chiefly decomposing fine particulate organic matter (commonly 500 μ diameter or less), but, because they are generally indiscriminate feeders, they also ingest large quantities of algae and significant amounts of microscopic animals. It is useful to differentiate several subcategories of collectors based on location of the food and mode of acquisition. **Filter feeders** capture particles suspended in the water by means of specially constructed nets (such as *Hydropsyche*), modified mouthparts (*Simulium*), or gills (mussels). **Gatherers** (such as various mayflies) scoop, brush, or otherwise engulf deposited, loose surficial sediments. **Sediment miners** (such as tubificid worms and a number of midge larvae) burrow through deposited fine particle substrates at varying distances below the surface.

The third category, **SCRAPERS**, feed on the matrix of algae, microbes, and associated fine organic matter attached to rocks, aquatic macrophytes, or other submersed surfaces. Scrapers may be either discriminant or indiscriminant feeders but commonly ingest large amounts of algae. Modes of ingesting attached materials other than by actual scraping (such as nibbling, tearing, or cropping) are included under this heading.

The last category, **PREDATORS**, ingest living animal tissue (mainly other aquatic invertebrates) by capturing prey and ingesting whole or large parts (engulfers) or piercing the body and withdrawing fluids (piercers).

Figure 53 shows the distribution of functional feeding groups in relation to changing riparian conditions with increasing stream size. As shown, shredders are predominantly in the headwaters in association with high amounts of coarse particulate organic matter (CPOM) from the adjacent riparian area. Scrapers (grazers) predominantly occupy the shallow, more open intermediate-sized streams. Collectors are important in streams of all sizes, but they change in composition in response to particle size and makeup of the fine particulate organic matter (FPOM) and its occurrence on the stream bottom or in the water. The species composition of the predators also changes, but they remain a relatively constant proportion of the total consumers (after Vannote and others 1980).

The basic procedure for using the functional feeding group approach is simple and straightforward. Usually the invertebrates are separated, on the basis of their taxonomy, into the lowest unit practicable (preferably species or genus) and censused (see Minshall 1981). Then, the abundance or biomass values are assigned to functional feeding group categories on the basis of mouthpart morphology, food habits, feeding behavior, or all of these (see, for example, Minshall 1981, table 23). Ideally, functional feeding designations should be determined separately for each study, but frequently they are based on an examination of published results or of compilations of these results prepared by Merritt and Cummins (1984) (see table 24 for an earlier, more general version). In practice, the power of the technique is dependent on the care with which taxa are assigned to functional groups. Not only may closely related taxa (for instance, those within the same genus or family) show divergent feeding modes, but even within a single species, feeding structures and behavior may change as the invertebrate grows. In many cases, particularly in small (first to third order) headwater streams, the relative shift from autochthony to allochthony or vice versa should be reflected by changes in the ratio of shredder (sh) to scraper (sc) abundance or biomass:

sh/sc >1 = allochthonous

sh/sc <1 = autochthonous.

The idea that the functional feeding group composition of stream invertebrate communities may be a useful means of evaluating the status of riparian habitats stems from the realization that (1) trophic relationships constitute important forces in the evolution and ecology of aquatic invertebrates and (2) the trophic conditions of a stream are largely regulated by the riparian environment (Swanson and others 1982; Cummins and others 1984; Minshall and others 1985). The riparian environment controls the amount of sunlight and terrestrial plant matter reaching a stream. These factors in turn substantially determine whether the food base will be generated mainly from within the stream (autochthonous) or from without (allochthonous).

For example, provided that all other factors are equal, the more shaded a stream is, the less algae or vascular hydrophytes it will produce and the more dependent it will be on allochthonous food supplies. Unshaded streams in the United States commonly receive 1.2 to 1.8 × 10^6 kcal/m^2/yr of sunlight, whereas shaded ones may be reduced to only 10 percent or less of the total light available. Likewise, shaded deciduous forest streams commonly receive around 2,500 kcal/m^2/yr of terrestrial litter, whereas unshaded desert streams may receive less than 75 kcal/m^2/yr. Because solar, terrestrial, and other factors change as a stream becomes larger (especially wider) and more distant from its usually forested headwaters, differences in functional feeding group composition associated with stream size may be expected (Vannote and others 1980) (fig. 53). The association between predominant food type and functional feeding group composition has been found to hold in a number of relatively natural stream settings (Wiggins and Mackay 1978; Cummins and others 1981; Hawkins and Sedell 1981; Minshall 1981; Minshall and others 1983).

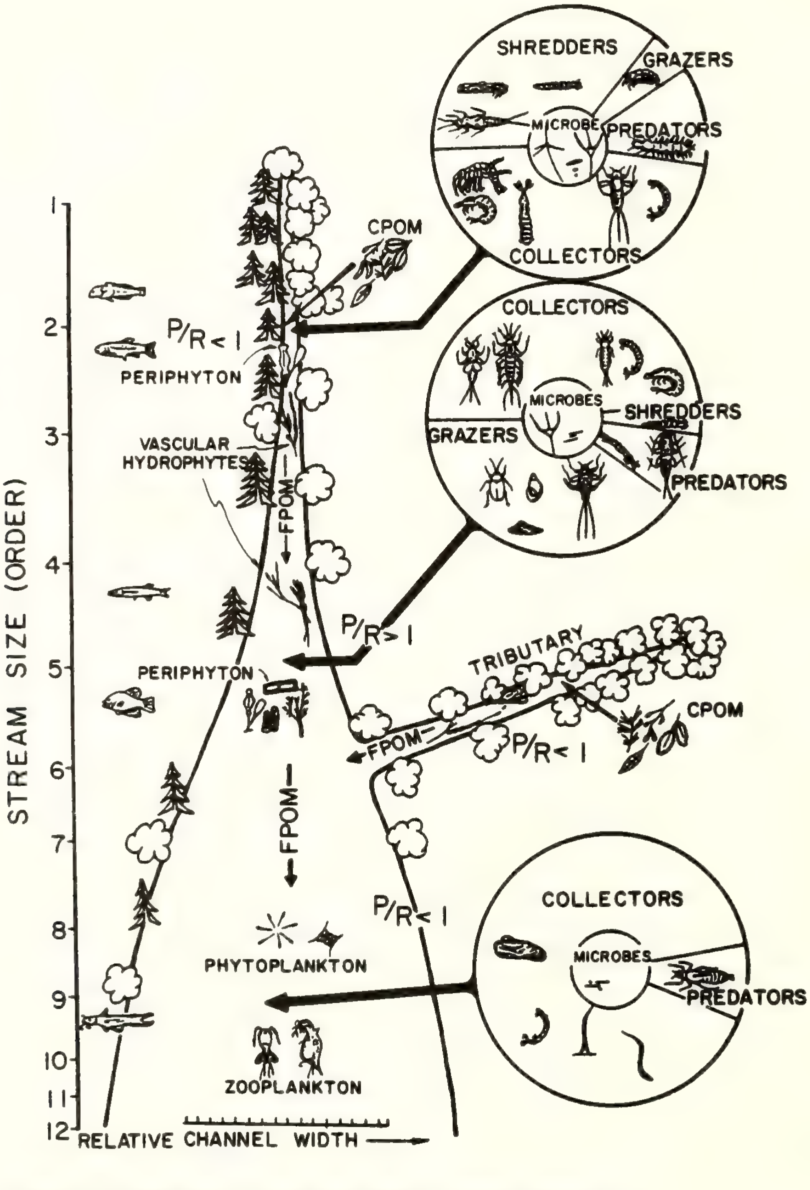

SHREDDERS
GRAZERS
MICROBE
PREDATORS
COLLECTORS
CPOM
P/R < 1
PERIPHYTON
VASCULAR HYDROPHYTES
FPOM
COLLECTORS
MICROBES
SHREDDERS
GRAZERS
PREDATORS
P/R > 1
PERIPHYTON
TRIBUTARY
CPOM
FPOM
P/R < 1
FPOM
P/R < 1
COLLECTORS
MICROBES
PREDATORS
PHYTOPLANKTON
ZOOPLANKTON
STREAM SIZE (ORDER)
1
2
3
4
5
6
7
8
9
10
11
12
RELATIVE CHANNEL WIDTH

Figure 53—Distribution of functional feeding groups in relation to changing riparian conditions with increasing stream size. As shown, shredders are predominantly in the headwaters in association with high amounts of coarse particulate organic matter (CPOM) from the adjacent riparian area; scrapers (grazers) predominantly occupy the shallow, more open intermediate-sized streams. Collectors are important in streams of all sizes but change in composition in response to particle size and makeup of the fine particulate organic matter (FPOM) and its occurrence on the stream bottom or in the water. The composition of the predators also changes, but they remain a relatively constant proportion of the total consumers (after Vannote and others 1980).

Alteration of the riparian habitat generally impacts the type and density of terrestrial vegetation and the width and depth of the stream. These changes will affect the relative amounts of autochthonous and allochthonous food resources in the stream. The quality and absolute amounts of the food may also change dramatically. Consequently, the condition of the riparian habitat should be reflected in the abundance and composition of the stream invertebrate community. In general, removal of terrestrial vegetation from first to third order streams through grazing, trampling, burning, or logging can be expected to reduce the abundance and biomass of shredders and increase those of scrapers. Shifts within the collector category may also occur (such as filter feeders may increase in response to increases in the amounts of suspended organic matter), but predator levels may remain constant if only the kind and not the amount of prey is affected. Qualitative differences in the terrestrial vegetation and in the age of the stand may also affect the structure and function of the invertebrate community. For example, Vannote (1969) found that the replacement of the climax species (hickory-maple) by American beech-northern red oak in eastern deciduous forests resulted in reduced growth of shredders, especially *Tipula abdominalis*. Presumably *Tipula* is less successful now than before the change in forest type. Molles (1982) studied the caddisfly (Trichoptera) communities associated with aspen, spruce-fir, and mixed conifer forests in New Mexico. He found that the ratio of shredder to grazer biomass was higher in conifer streams (3:1) than in aspen streams (0.06:1) and attributed this to the higher retention capacity for allochthonous detritus in the conifer streams due to the greater number (five times) of logs occurring in them. In terms of forest succession, aspen stands are viewed as being younger than conifer stands.

The functional feeding group method, as applied to managed watersheds, is still in the experimental stage. There are few results available to test it. Hawkins and others (1982) studied streams in old-growth, clearcut, and second-growth forests of the Oregon Cascade Mountains. They found that shredders were no more abundant in shaded streams than in those lacking a riparian canopy. Also, the relative abundance of detritivore shredders was not always highest in shaded streams, nor was the relative abundance of scrapers always highest in unshaded streams. Similar results have been obtained in Idaho from studies of grazed and ungrazed sections of a single stream and in an assortment of burned and unburned watersheds (Minshall unpublished). Hawkins and others (1982) also found that open canopy (clearcut) streams had a much higher ratio (14:1) of collectors to scrapers than did partial (second-growth) or closed (old-growth) canopy streams (4:1). These findings are supported by studies of grazed (9:1) and ungrazed (4:1, 2:1) sections of the same stream, but results for streams in burned and unburned watersheds are variable (Minshall unpublished).

Clearer patterns could emerge from the widespread testing of the functional feeding group approach, but until that time arrives, it is best used in conjunction with more conventional approaches to community analysis—comparisons of richness, abundance, diversity, and so forth as suggested by Platts and others (1983). For instance, Newbold and others (1980) found that Euclidean distance and Shannon-Weiner diversity gave the clearest indication of logging effects of the various indices they examined.

Description of population responses should not be abandoned. Hawkins and others (1982), for example, found differences in both absolute and relative abundances of individual taxa in shaded and unshaded streams even though differences in streamside vegetation were not always evident from community level properties.

Should the functional feeding group approach prove to be a sensitive indicator of the condition of the riparian habitat, its use could greatly simplify evaluation of stream ecosystem responses to environmental change. But even if this goal is not attained, it should provide aquatic biologists and resource managers with an additional tool for measuring riparian impacts.

PLANTING OF RIPARIAN SITES

Riparian sites are an intricate part of the watershed resources of the Western United States (Thomas and others 1979). Riparian areas normally align stream courses that often traverse many plant communities, topographic sites, and climatic conditions. The entire route of a stream is interrelated and major disruptions to the stream or watershed can influence a significant portion of the course.

Livestock grazing, timber harvesting, road construction, agricultural cropping, and recreational uses have disrupted the vegetation and stability of many riparian areas (Council of Agricultural Science and Technology 1974; Leopold 1974). Once the vegetative cover of the channel is reduced, stream erosion may quickly alter the site and hinder natural or artificial restoration (Monsen 1983). Disturbances to the vegetation of other range or wildland sites are usually not so critical. The vegetation of upland sites may be seriously disrupted, yet degradation usually ceases as livestock grazing or other impacts are regulated. In contrast, disturbed riparian areas may continue to degrade after the activity stops. Water control structures may be required to alleviate erosion and allow recovery.

Controlling livestock grazing and regulating other uses of riparian sites is not always easy (Platts 1981b). Grazing adjacent upland rangelands is often dependent upon access to riparian communities. Eliminating riparian areas from livestock grazing usually impedes the effective use of associated uplands.

A more extensive revegetative plan is usually required to restore and stabilize riparian disturbances than is needed to rectify disruption to upland plant communities. Methods required for interplanting woody and herbaceous species onto unstable streambanks have not been fully developed. In addition, woody and aquatic species adapted to riparian sites are not commercially available for large-scale plantings. Research has not yet been able to determine the most appropriate techniques to propagate and plant native or introduced species that are adapted to riparian disturbances.

Factors Influencing Revegetation

The following list discusses factors that influence restoration practices.

1. Alteration of the riparian vegetation and soil may occur from on-site impacts, or as a result of poor management of other portions of the watershed (Megahan and Kidd 1972). Proper management of the entire watershed is essential prior to enactment of restoration measures of the riparian communities. Restoration of riparian sites may be conducted simultaneously with treatment of other portions of the watershed. Unless adjoining areas are reasonably stable, repair of riparian disturbance will not be effective.
2. Riparian sites usually are extremely heterogeneous, containing different plant communities, topographic conditions, parent materials, and soils within a short distance (Odum 1971). Remedial treatments must be applicable to the different conditions encountered. For example, unstable, steep banks may occur immediately adjacent to wet and boggy meadows, requiring different site preparation practices, planting techniques, and plant materials.
3. Different treatments are often required to correct separate problems—control surface erosion, eliminate bank slumping, provide shade to the stream, control weeds, and provide concealment for wildlife.
4. Riparian sites are often narrow, irregularly shaped corridors that are not accessible to conventional planting equipment. Although only small areas may require treatment, extensive erosion, sedimentation, and plant alteration may have occurred, thus requiring special equipment for restoration.
5. The dense and frequently storied assembly of many plant species is required to maintain riparian site stability. Grazing and other impacts have often reduced plant density or resulted in the removal of specific species. The loss of key species may seriously affect the persistence of other plants. To be successful, restoration may require the reestablishment of a complex array of plants. Reestablishing woody plants is often the most critical.
6. Many sites are so seriously altered that extensive restoration measures will be required to restrict further losses of soil and vegetation and reestablish a desirable plant cover.
7. Stabilization of the streambank with vegetation is often the principal concern in restoration. Revegetation may also be required to provide shade to the stream, forage for livestock, or wildlife habitat.
8. Riparian sites have often been so seriously altered that the original vegetation is no longer adapted to the disturbances. Thus attempts to restore the original complement of plants may not be practical. However, unless a grouping of plants similar to the original community can be established, aquatic and terrestrial resources may not be fully restored.
9. Noxious weeds and less desirable species have often invaded riparian disturbances. Weeds often must be removed to improve the site and allow for planting. These plants do not always provide adequate soil protection or enhance aquatic habitat. Weeds may be spread by the stream to occupy downstream disturbances and interfere with the establishment of more desirable species.
10. Site preparation is usually required to accommodate planting. Some reduction of the existing plant cover may be necessary to eliminate competition to newly seeded or planted species. However, reduction of streambank stability by plowing or similar methods of plant removal is hazardous. Thus, treatments normally include interseedings, selective, or delayed

plantings. By such procedures, small areas can be treated in sequential intervals to retain existing plant cover and encourage natural recovery.

11. Seasonal runoff and flooding influence planting dates as well as establishment and survival of new seedlings or transplants (Aldon 1970). Sites may be covered with water in the spring for a few days or weeks. Planting is frequently delayed by flooding until air temperatures and precipitation patterns are no longer conducive to seedling survival (Cluff and others 1983).

Disturbances may be seeded in the later summer or fall, yet fall-germinated seedlings may not be able to survive spring runoff. Many riparian species survive or are propagated by flooding (Kozlowski 1984). However, small seedlings usually are not as adaptive as larger plants. Seasonal runoff also disrupts and seriously damages prepared seedbeds. Transplanting large stock is often required to resist the effects of flooding and scouring.

12. Protection of young plantings is essential for plant establishment and survival. Protection from grazing may be required for a number of years to allow plants to attain a reasonable size and furnish soil protection. Transplanting large stock may be necessary to overcome the influences of grazing and flooding.

Restoration by Natural Means

Artificial revegetation is not the only means to reattain a satisfactory plant cover. Natural recovery can often occur if areas are protected from livestock grazing or other destructive effects (Meehan and Platts 1978; Vallentine 1971). If a remnant composition of desirable plants exists, natural restoration may be most practicable. Artificial revegetation normally should not be employed unless satisfactory recovery cannot be achieved by natural means within an acceptable period. Most riparian shrubs and trees are capable of resprouting and can recover from extensive use. Nonsprouting species are slower to recover and may reappear erratically. A satisfactory seed source may exist, but seedbed conditions on disturbed sites are not always conducive to seedling establishment. Although protected sites may recover slowly at first, once soil surfaces stabilize new plants often appear rapidly.

Some native herbs are difficult to propagate and plant, yet these species contribute to streambank stability. Few introduced herbaceous plants produce the root mass and streambank stability of many important native herbs. Few, if any, native *Carex* or other grasslike plants are commercially available. Where possible, these herbs should be allowed to recover naturally. Plowing or spraying should be done carefully to retain these plants. Species listed in table 25 are some of the principal understory herbs of value for streambank stabilization.

Table 25—Distribution and rooting characteristics of select native herbs for riparian sites. Information in part is from Lewis (1958). Scientific names from Welsh and others (1981).

Species	Areas[1]	Habitat	Abundance	Rooting habit	Comments
Carex aquatilis Water sedge	Asp.-SF	Wet meadows	Abundant	Caespitose, long rhizomes	Excellent streambank stability, highly palatable. Principal species for revegetation.
Carex aurea Golden sedge	Val.-SF	Marsh, wet meadows	Frequent	Caespitose, long rootstocks	Widely distributed, good ground cover.
Carex disperma Softleaved sedge	Asp.-Alp.	Swamps, meadows	Frequent	Caespitose, long rhizomes	Shady areas, solid mat, moderate vigor.
Carex douglasii Douglas sedge	PJ-Asp.	Dry meadows, alkali tolerant	Abundant	Creeping rootstocks, long clums	Adapted to compact soils, low palatability, increases under grazing.
Carex elynoides Black sedge-root	Alp.	Open, dry meadows	Common	Caespitose	Vigorous, abundant.
Carex hoodii Hood sedge	Mtn.B.-SF	Open parks, drainage ways, bottoms	Abundant	Densely caespitose	Excellent ground cover, useful forage species.
Carex lanuginosa Woolly sedge	Val.-SF	Dry to wet meadows	Abundant	Caespitose, long rootstocks	Very robust, principal species for streambank stabilization.
Carex lenticularis Kellogg sedge	Mtn.B.-SF	Wet meadows, marshes	Abundant	Caespitose, long rootstocks	Pioneer species, invades water's edge.
Carex microptera Smallwing sedge	Mtn.B.-Asp.	Meadow edges	Abundant	Densely caespitose	Good cover for streambank, palatable, spreads by seeds, widely distributed.

(con.)

Table 25—(Con.)

Species	Areas[1]	Habitat	Abundance	Rooting habit	Comments
Carex nardina Hepburn sedge	Alp.	Open meadows	Abundant	Densely caespitose	Short stature, open cover.
Carex nebrascensis Nebraska sedge	Val.-Asp.	Marshes and meadows, alkali tolerant	Common	Strongly rhizomatous	Excellent soil stabilizer, palatable, widely distributed.
Carex nigricans Black alpine sedge	SF-Alp.	Well-drained meadows	Frequent	Creeping rootstock	Good cover for wet areas.
Carex praegracilis Slim sedge	Val.-Asp.	Dry to moist, alkali bottomlands	Abundant	Long, creeping rootstocks	Large plant, dense, persistent, moderately palatable.
Carex rostrata Beaked sedge	Val.-SF	Streams, water's edge, standing water	Abundant	Culms from stout, long rhizomes	Principal species for streambank stabilization, low palatability, fluctuating water level, wide elevational range.
Carex rupestris Rock sedge	Alp.	Dry slopes and meadows	Abundant	Short rhizomes	Vigorous, spreads rapidly, limited distribution.
Carex saxatilis	LPP-SF	Water's edge	Abundant	Culms from long, creeping rootstocks	Excellent streambank cover, limited distribution.
Carex scirpoidea Downy sedge	Alp.	Dry and wet meadows	Abundant	Rhizomatous	Vigorous, spreads rapidly.
Carex simulata Analogne sedge	PP-SF	Bogs and wet meadows, calcareous soils	Frequent	Long, creeping rootstocks	Excellent cover, widely distributed.
Carex vallicola Valley sedge	Sage-Asp.	Dry slopes	Abundant	Caespitose	Spreads onto dry grass-sage sites.
Eleocharis palustris Spikerush	Val.-SF	Wet meadows and streams, alkali tolerant	Abundant	Rhizomatous	Spreads rapidly, low palatability, wide elevational range.
Juncus arcticus var. *balticus* Baltic rush	Val.-Asp.	Wet and semiwet meadows	Abundant	Rhizomatous	Principal species for stabilization. Use adapted ecotypes, spreads aggressively, persists with grazing.
Juncus drummondii Drummond rush	LPP-Alp.	Wet and dry meadows	Common	Caespitose	Spreads after disturbance, occupies infertile soil.
Juncus ensifolius Swordleaf rush	Sage-SF	Streams, wet meadows, seeps	Abundant	Strongly rhizomatous	Moderately palatable, wide elevational range.
Juncus longistylis Longstyle rush	Sage-SF	Wet meadows, streams	Common	Rhizomatous	Moderately palatable.
Juncus torreyi Torrey rush	Val.-PJ	Streams, wet meadows, seeps, alkali tolerant	Common	Strongly rhizomatous	Spreads onto disturbances.
Scirpus acutus Tule bulrush	Val.-Mtn.B.	Lake edge	Abundant	Rhizomatous	Tall, rank, dense patches, restricted to water's edge.
Scirpus maritimus Saltmarsh bulrush	Mtn.B.	Lake edge, stream bank, alkali sites	Abundant	Rhizomatous	Dense patches, spreads rapidly.

---

[1] Areas: Alp. = alpine, SF = spruce-fir, Asp. = aspen, LPP = lodgepole pine, PP = ponderosa pine, Mtn.B. = mountainbrush, PJ = pinyon-juniper, Sage = big sagebrush, Val. = valley.

Site Preparation and Alterations

Site disturbances must be evaluated relative to their effects on seedbed or planting conditions. Disturbances may have eliminated desirable plants, altered or removed the soil, or allowed for the invasion of weeds. Prior to treatment the entire route should be surveyed and classified by site conditions.

Physical Structures—The erection of physical structures, either temporarily or permanently, is often required to protect the seedbed or streambank from erosion (Horton 1949). Temporary structures, including logs, trees, or netting may be used during the period of plant establishment to divert or reduce stream impacts. However, during years of excessive flooding these structures might not be effective. Permanent structures are often required to stabilize erosive surfaces and prevent mass slumping. Physical structures are expensive and cannot be erected at every site. Consequently, they are usually located in the most critical areas. The reintroduction of beavers with their dam building is often an effective method of stabilizing the streambanks.

Regrading and Topsoiling—Steep banks may not be successfully planted unless the slope is reshaped. Reshaping enhances the success of both seeding and transplanting. Reshaping is usually more effective than construction of retaining or diversion structures. However, regrading is not always possible and may not be effective if serious erosion is allowed to continue. Streambanks should not be reshaped if the existing plant cover is able to stabilize the site through protective management.

Topsoiling is an effective and practical method of treating riparian sites and is important in improving the seedbed. Seedling establishment can be enhanced by slight modification of the soil surface. Topsoiling should be considered when dams, bridges, or other physical changes are made. A thin layer of topsoil can be applied over an entire site, or select but restricted spots may be covered with a thick layer. Isolated sites that are topsoiled and planted recover quickly and tend to moderate and enhance the improvement of untreated areas. Selective treatment is useful to protect erodible portions of the streambank.

Young plantings may require more than 1 year to become firmly established. An additional 2 or 3 years are needed to provide appreciable soil protection. Exposing large segments of the streambank to flooding for this period may not be advisable. Treating small segments of the stream over 2 to 5 years may be more costly but is recommended.

Reduction of Weeds and Plant Competition—New seedlings or transplants cannot be established amid an existing competitive stand of plants. However, complete elimination of the existing cover is not always required or advisable. Although improvements may ultimately result from seeding or transplanting, complete elimination of existing species to facilitate planting may be advisable only on sites where serious erosion is not expected.

Because soil stability is much more critical to riparian conditions than to upland sites, plant cover must be maintained during the planting period. If destructive erosion does not occur, undesirable plants can be completely removed by plowing, disking, spraying, and so forth. Interseeding or spot treatment is advisable for more erodible sites.

Neither seeded nor transplanted species can be established on sites supporting existing plant cover unless some means is provided to control the existing competition. Neither willow cuttings nor rooted stock can be successfully planted directly into an existing understory (Neilard and others 1981). Transplants are usually less susceptible to competition than are direct seedings. Transplanting small segments of sod or plugs of various grasses, carex, or broadleaf herbs can be accomplished without extensive site preparation. However, unrooted slips or stem cuttings of willow or other shrubs are not well suited to unprepared sites. Interplanting rooted or unrooted shrubs onto unprepared sites should be avoided. This practice is quite often employed and usually fails.

Seedbed Preparation—Construction activities such as plowing to remove weeds or regrading the streambank are treatments that do not necessarily create a favorable seedbed. These practices should not be confused with seedbed preparation. A firm soil surface and an adequate supply of soil moisture are critical to seeding and transplanting.

If site alteration treatments are used to develop a seedbed, these practices must be employed at a time and under conditions favoring a quality seedbed. Treatments should not be conducted when soil compaction would occur or if excessive drying of the seedbed would result.

Proper seedbed and planting surfaces can be achieved by allowing time for loose soils to settle, or by mechanical compaction. Highly compact or hard surfaces can be loosened by ripping, plowing, or disking. Storage of soil moisture can be accomplished by scheduling treatments to allow water to collect and infiltrate the soil.

Proper equipment should be used. Drill seeders and other conventional seeding equipment can be operated on rough irregular surfaces. Compaction wheels and furrow openers can be adjusted to create suitable surface conditions.

Barren sites are often erroneously considered appropriate areas for planting without regard to seedbed characteristics. Barren areas may be void of plant competition but may not be conducive to seeding.

Plowing and Disking—Plowing and disking are most often used to uproot and reduce dense stands of undesirable plants (Long and others 1984). Plowing is usually confined to deep soils, whereas disking is better adapted to shallow and more rocky sites. Disking is more appropriate in areas having a large accumulation of litter. Both items of equipment can be used to uproot sod-forming species. Disking or plowing may be used in conjunction with herbicides to remove the most persistent vegetation.

Plowing is usually done when soils are moist but not wet or excessively dry. Surface litter and soil structure are altered by plowing. Semiwet and wet meadows contain a high percentage of organic matter. Plowing may cause these soils to settle and crust if worked at an inappropriate time. Prior to planting plowed sites must be allowed to settle, or a firm seedbed can be created by harrowing. Planting depths cannot be properly regulated if attempts are made to seed a loosely plowed surface. Plowing can cause rapid drying of the seedbed. However, harrowing the surface to create a loose surface mulch will prevent drying.

Disking is a more versatile technique than plowing. Various size disks are available. Some are almost as effective as a moldboard plow, whereas others create much less soil disturbance. The digging depth of the disk can be adjusted to penetrate the soil to the depth desired. Small, lightweight disks can be used with a variety of tractors. These implements can be operated on small rough sites without serious damage to the machinery.

Disking is recommended for treating sites where a residual amount of vegetation is to be left in place. Disks can be adjusted to leave some vegetation on the surface or have it plowed into the soil. Seeding devices can be mounted on the disk to distribute seed directly behind or in front of the machine. Natural soil sloughing frequently occurs to cover the seed.

Herbicides for Plant Control—Herbicides can be applied to remove or control undesirable vegetation, leaving other desirable vegetation. Contamination of the stream is a concern when herbicides are used. However, recent advances with new herbicides, formulations, and application techniques have expanded the potential use of herbicides for riparian areas.

Because some species cannot be easily controlled by mechanical treatment, herbicides are particularly advantageous. More importantly, herbicides provide a rapid control method for treating poorly accessible riparian sites, an advantage because the planting season is usually short. However, use of herbicides does not always result in a suitable seedbed, and mechanical treatments may also be required to accomplish direct seedings.

Herbicides should be applied using ground sprays or hand-operated units. Both can be safely operated and large areas can be treated effectively. Hand spraying is the most efficient method of plant control when transplanting shrubs into a herbaceous understory. Glyphosate (Roundup™) can be used to eliminate most riparian species including rhizomatous grasses, grasslike plants, and broadleaf herbs. The herbicide is effective when applied at a rate of 1 pint per acre. Small spots, approximately 30 inches in diameter, are sprayed. Woody transplants can be planted immediately after the herbicide is applied although a delay of half to a full hour is recommended. An agricultural dye is added to the herbicide to mark the sprayed spots. Spot spraying and transplanting minimizes disruption to the existing vegetation. Rhizomatous plants maintain streambank stability, and sprayed spots will often collapse as the root mass dies. Entire sections of the streambank can fail or slump away if a large number of spots are closely aligned near the edge of the bank. The best recommendation is to not use herbicides close to streambanks.

For specific herbicide uses, application rates and systems, the following references are recommended: Alley and others (1978), Cords and Artz (1976), Heikes (1978), Whitson and others (1985), Jensen and others (1980), USDA Forest Service (1984), Vallentine (1980, 1983), and Welty and others (1981).

Interseeding and Interplanting—Interseeding is a means of preparing and planting the site without complete removal of the existing vegetation. Various drills, disks, scalpers, and spray units have been adapted to interplant small strips, patches, or spots while leaving most of the existing vegetative area undisturbed.

Interplanting shrubs with herbaceous plants is a practical method of reestablishing woody plants in most riparian sites. Shrubs cannot be established without first reducing the understory competition. Shrub transplants compete much more successfully than direct seedings.

Seeding Riparian Communities

Flooding dictates the planting dates. Areas not subject to flooding can be fall-planted or spring-planted depending upon climatic conditions. Areas that are flooded annually should be seeded after spring runoff. Fall plantings can be made if sites are not damaged by spring runoff.

Covering seed is essential to germination and seedling establishment. Broadcast seeding is not acceptable unless some means of seed coverage is provided. A mixture of plants is often seeded to furnish an immediate and dense ground cover. Harsh sites are difficult to seed, and adherence to proven practices must be followed. Applying excessive amounts of seed will not compensate for poor seeding techniques.

Riparian areas can be seeded with the same equipment and the same techniques used to plant upland ranges. Seeding can be accomplished using drills, cultipack seeders, interseeders, hydro-row dry-seeders, or hand planting. Aerial seeding is also appropriate, but unless helicopters are used, riparian sites are usually too small for this technique. Sites that can be planted with conventional equipment usually can be drill seeded. Unless the sites are accessible and reasonably large, seeding with tractor-drawn equipment is impractical. Smaller sites can be broadcast seeded by hand, after which the seed should be raked into the soil surface.

Plant Selection and Uses

In addition to the use of native herbs that occur within the planting sites, various introduced species can be relied upon for direct seeding and transplanting (Horton 1949; Doran 1957; Plummer and others 1968). While such species are introduced to provide immediate soil protection, they must also possess both a vegetative growth habit and root mass capable of furnishing site protection when subjected to stream erosion (Ree 1976). The new species must also allow for natural succession and the ultimate development of a desired community. Planting aggressive and competitive rhizomatous species can prevent the entry of other useful plants, unless these are included in the initial mixture.

Transplanting small plugs or large pads is a viable method of establishing herbaceous plants. Transplants can be reared or dug from wildland sites to furnish suitable materials. But because planting costs are high, only small areas are usually treated in this manner.

Species listed in tables 26 and 27 are recommended for either seeding or transplanting.

Table 26—Grasses recommended for direct seeding and transplanting riparian sites. Scientific names from Welsh and others (1981).

Species	Areas of adaptation[1]	Origin	Seeding trait	Transplant capability	Growth rate	Rooting habit	Salinity tolerance[2]	Flooding tolerance	Palatability	Spreadability
Agropyron elongatum Tall wheatgrass	Mtn.B.-V	Introduced	Excellent	Good	Rapid	Large clump	MT	Moderate	Fair	Good
Agropyron repens Quackgrass	Asp.-V	Introduced	Fair	Excellent	Slow	Rhizomatous	MT	Moderate	Good	Excellent
Agropyron smithii Western wheatgrass	PP-SDS	Native	Poor	Excellent	Slow	Rhizomatous	MS	Moderate	Good	Good
Agropyron trachycaulum Slender wheatgrass	SF-PJ	Native	Excellent	Excellent	Rapid	Rhizomatous	MS	Sensitive	Excellent	Good
Agrostis stolonifera Redtop	Salp.-SF	Introduced	Fair	Good	Moderate	Rhizomatous	MS	Moderate	Good	Excellent
Alopecurus pratensis Meadow foxtail	Alp.-Mtn.B.	Introduced	Excellent	Good	Rapid	Rhizomatous	MT	Tolerant	Good	Excellent
Bromus carinatus Mountain brome	Alp.-PJ	Native	Excellent	Excellent	Rapid	Rhizomatous	MT	Moderate	Good	Good
Bromus erectus Meadow brome	Alp.-PJ	Introduced	Excellent	Excellent	Moderate	Rhizomatous	MT	Moderate	Good	Excellent
Bromus inermis Smooth brome	Alp.-Mtn.B.	Introduced	Good	Excellent	Moderate	Rhizomatous	MT	Moderate	Good	Excellent
Calamagrostis canadensis Bluejoint reedgrass	SF-Sage	Native	Good	Excellent	Moderate	Rhizomatous	MT	Tolerant	Good	Excellent
Calamagrostis epigeois Chee reedgrass	Alp.-PJ	Introduced	Poor	Good	Slow	Rhizomatous	MT	Tolerant	Good	Good
Dactylis glomerata Orchardgrass	Alp.-Sage	Introduced	Good	Good	Rapid	Bunch	MS	Sensitive	Excellent	Fair
Deschampsia caespitosa Tufted hairgrass	Alp.-SF	Native	Poor	Fair	Slow	Bunch	MT	Tolerant	Fair	Poor
Distichylis spicata Saltgrass	V	Native	Poor	Excellent	Slow	Rhizomatous	T	Tolerant	Fair	Excellent
Elymus cinereus Great Basin wildrye	Mtn.B.-V	Native	Good	Good	Moderate	Large clump	T	Moderate	Good	Fair
Elymus giganteus Mammoth wildrye	Mtn.B.-Sage	Introduced	Fair	Good	Moderate	Rhizomatous	T	Tolerant	Good	Good
Elymus junceus Russian wildrye	Mtn.B.-V	Introduced	Fair	Good	Moderate	Bunch	T	Moderate	Excellent	Fair
Elymus triticoides Creeping wildrye	JP-V	Introduced	Good	Excellent	Moderate	Rhizomatous	T	Tolerant	Poor	Good
Festuca arundinacea Reed fescue (alta or tall)	Asp.-SDS	Introduced	Excellent	Excellent	Rapid	Rhizomatous	T	Tolerant	Good	Excellent
Hordeum brachyantherum Meadow barley	Alp.-Asp.	Native	Excellent	Excellent	Moderate	Bunch	T	Tolerant	Fair	Good
Lolium perenne Perennial ryegrass	SF-PP	Introduced	Excellent	Good	Rapid	Small bunch	MT	Sensitive	Good	Good
Phalaris arundinacea Reed canarygrass	Asp.-V	Native	Poor	Excellent	Slow	Rhizomatous	T	Tolerant	Fair	Excellent

Phleum pratense Timothy	Asp.-Mtn.B.	Introduced	Good	Good	Rapid	Bunch	MS	Moderate	Good	Good
Poa pratensis Kentucky bluegrass	Asp.-PJ	Introduced	Fair	Good	Slow	Rhizomatous	MT	Moderate	Good	Excellent
Poa secunda Sandberg bluegrass	Mtn.B.-Sage	Native	Fair	Good	Slow	Bunch	MT	Moderate	Good	Fair
Sitanion hystrix Bottlebrush squirreltail	Mtn.B.-SDS	Native	Good	Fair	Moderate	Bunch	MT	Moderate	Good	Good
Sporobolus airoides Alkali sacaton		Native	Fair	Good	Slow	Bunch	MT	Moderate	Good	Excellent

---

[1] Areas of adaptation—Alp. = alpine; SF = spruce-fir; Asp. = aspen; Mtn.B. = mountainbrush; PJ = pinyon-juniper; PP = ponderosa pine; Sage = big sagebrush; Salp. = subalpine; SDS = salt desert shrub; V = valley bottom.

[2] Salinity tolerance—S = sensitive; MS = moderately sensitive; MT = moderately tolerant; T = tolerant.

Table 27—Broadleaf herbs recommended for planting of riparian sites. Scientific names from Welsh and others (1981).

Species	Areas of adaptation[1]	Origin	Seeding trait	Transplant capability	Growth rate	Salinity tolerance[2]	Flooding tolerance	Palatability	Spreadability
Achillea millefolium lanulosa Western yarrow	Alp.-V	Native	Excellent	Excellent	Rapid	MS	Moderate	Poor	Excellent
Artemisia ludoviciana ludoviciana Louisiana sagewort	Alp.-Sage	Native	Excellent	Excellent	Rapid	MS	Moderate	Poor	Excellent
Aster chilensis adscendens Pacific aster	Asp.-V	Native	Poor	Excellent	Moderate	MS	Moderate	Excellent	Excellent
Bassia hyssopifolia Fivehook bassia	PJ-SDS	Native	Excellent	Good	Rapid	T	Tolerant	Good	Good
Coronilla varia Crownvetch	PJ-Mtn.B.	Introduced	Good	Excellent	Rapid	MS	Moderate	Good	Good
Epilobium angustifolium Fireweed	Asp.-Mtn.B.	Native	Excellent	Good	Rapid	S	Moderate	Fair	Excellent
Heracleum lanatum Common cowparsnip	Alp.-Mtn.B	Native	Poor	Poor	Poor	S	Sensitive	Excellent	Fair
Linum lewisii Lewis flax	Asp.-Sage	Native	Excellent	Good	Moderate	S	Sensitive	Good	Good
Medicago lupulina Black medic	Asp.-Sage	Introduced	Excellent	Good	Moderate	MT	Moderate	Good	Good
Medicago sativa Alfalfa	Asp.-Sage	Introduced	Excellent	Good	Rapid	MT	Moderate	Excellent	Fair
Melilotus officinalis Yellow sweetclover	Asp.-Sage	Introduced	Excellent	Poor	Rapid	MT	Moderate	Good	Excellent
Potentilla glandulosa glandulosa Gland cinquefoil	Asp.-PP	Native	Good	Excellent	Moderate	S	Moderate	Fair	Good
Senecio serra Butterweed groundsel	Asp.-PP	Native	Good	Excellent	Moderate	S	Moderate	Good	Good
Sidalcea oregana Oregon checkermallow	Asp.-Mtn.B.	Native	Good	Good	Moderate	S	Moderate	Fair	Good
Smilacina racemosa amplexicaulis Western Solomons-seal	Asp.-Mtn.B.	Native	Poor	Fair	Slow	S	Moderate	Excellent	Fair
Trifolium fragiferum Strawberry clover	V	Introduced	Good	Fair	Moderate	MT	Moderate	Excellent	Excellent
Trifolium hybridum Alsike clover	Asp.-Mtn.B.	Introduced	Good	Fair	Moderate	S	Moderate	Good	Good
Valeriana edulis Edible valerian	Asp.-Mtn.B.	Native	Poor	Fair	Slow	S	Moderate	Fair	Fair

[1] Areas of adaptation—Alp. = alpine; Asp. = aspen; PP = ponderosa pine; Mtn.B. = mountainbrush; PJ = pinyon-juniper; Sage = sagebrush; SDS = salt desert shrub; V = valley bottoms.
[2] Salinity tolerance—S = sensitive; MS = moderately sensitive; MT = moderately tolerant; T = tolerant.

Planting Woody Species

Woody plants are normally required to provide streambank protection and to furnish habitat and forage to wildlife and livestock (Shafer and others 1982). Destruction of the woody overstory has often resulted from prolonged grazing. Once lost, these plants are difficult and costly to restore. Because shrubs and trees are not easily and reliably seeded, transplants are most often used to assure revegetation (Plummer and others 1968).

Without the presence of a protective overstory of shrubs and trees, many herbaceous species are unable to persist and provide streambank stability.

Species of willow (*Salix*) are the most universally abundant and most widely distributed of the woody taxa of the temperate riparian communities, while other shrubs are also present and may dominate in certain regions (Anderson and others 1984). Woody species that can be easily cultured have been relied upon for site improvement (table 28). Few native shrubs have been examined for riparian plantings. Chmelar (1974), Neiland and others (1981), and McCluskey and others (1983) examined cultural treatments required to propagate species of willow. Heebner and Bergener (1983) assembled information on red alder (*Alnus rubra*), and numerous studies have reported propagation practices for growing poplars (Phipps and others 1977; Peterson and Phipps 1976; Hansen and Phipps 1983). However, on-site evaluations and adaptability studies for most species are limited.

Propagating Woody Transplants—Woody species may be planted as (1) "slips" or unrooted stem cuttings, (2) rooted cuttings, (3) nursery (Shaw 1984; McDonald and others 1983) or greenhouse grown seedlings (Owston and Stein 1977; Landis and Simonich 1984), or (4) "wildlings," which are root sections or small seedlings dug from wildland sites (Doran 1957). Willows, poplars, dogwood, and plum are examples of species easily produced from cuttings, whereas other shrubs are normally grown from seed (table 28). Rooted stock have a definite advantage over unrooted cuttings, and should be used.

Most riparian shrubs can be effectively grown as transplant stock. Container-grown transplants can be produced in a shorter time than nursery-grown stock. However, bareroot stock is cheaper, much easier to handle, and plant survival exceeds or equals container plantings.

Rooting willow cuttings as nursery grown stock is advisable. Cuttings can be collected in the fall or spring as dormant slips. Cuttings are then planted into nursery beds and grown throughout the summer. The cuttings root and grow rapidly, requiring both root and stem pruning to contain desirable size. Rooted stock can be lifted, stored, and planted in a manner similar to other bareroot materials (Dahlgreen and others 1974; McDonald and others 1983).

Culture of Willows for Transplant Stock—While willows are usually grown more easily from cuttings than from seed, some species of willow respond better to other methods of culture (Chmelar 1974). Some species have preformed root primordia that occur in the stems (Carlson 1950; Haissig 1970). These develop adventitious roots that grow quickly. Species without preformed root primordia root poorly and some not at all. Densmore and Zasada (1978) report that of five species tested, plants associated with wet or riparian sites rooted easily and nonriparian species rooted poorly. Differences apparently were due to the presence or absence of preformed root primordia (table 29). Stem cuttings taken from the riparian species developed roots that arose along the entire length of the stem. Nonriparian species rooted only at the base of the cut. Chmelar (1974) found similar differences in the origin of new roots from 107 species of willow.

Studies of approximately 20 willows common to the Intermountain region also confirm that riparian-associated plants root better than nonriparian species (table 29). Roots developed throughout the stem of both riparian and nonriparian species but tended to be confined to the base of the cut for nonriparian selections.

Species that root quickly and freely are more likely to succeed and should be planted (table 29). All others should be rooted as nursery-grown or greenhouse-grown stock prior to field planting.

Chmelar (1974) found that stem and root formation began simultaneously for most easily rooted species. Root formation was delayed as much as 15 days, or longer than the time for leaf or stem development with poorly rooted species. Similar differences were recorded with Intermountain species propagated from stem cuttings (table 29). Plants that formulate roots after leaves and stems have developed are at a serious disadvantage. Favorable conditions may not persist long enough to assure rooting and establishment if slowly rooted species are field planted. New vegetative growth may persist for 1 or 2 years before plants succumb due to an inadequate root system.

Table 28—Woody species recommended for riparian disturbances. Scientific names from Welsh and others (1981).

Species	Areas of occurrence		Adaptation to disturbed sites	Methods[2] of culture	Establishment traits			Comments
	Zones[1]	Habitat			Seedling establishment	Growth rates	Soil stability value	
Alnus tenuifolia Thinleaf alder	SF-Mtn.B.	Stream edge and well-drained soils.	Excellent	NS, CS, DS	Excellent	Rapid	Excellent	Easily established, adapted to harsh sites, grows rapidly.
Amelanchier alnifolia Saskatoon serviceberry	Asp.-Mtn.B.	Well-drained soils, seeps occasional.	Good	NS, CS	Fair	Slow	Good	Slow to establish, sensitive to understory competition.
Artemisia cana viscidula Silver sagebrush	Asp.-Sage	Well-drained and moist soils, valley bottoms.	Fair	DS, NS, CS	Good	Rapid	Fair	Well adapted to exposed moist soils able to tolerate flooding for short time.
Artemisia tridentata tridentata Basin big sagebrush	Mtn.B.-SDS	Deep, well-drained soils, occasional flooding.	Excellent	DS, NS, CS	Good	Rapid	Fair	Useful for planting extremely disturbed and well-drained soils.
Artemisia tridentata vaseyana Mountain big sagebrush	Asp.-Mtn.B.	Well-drained soils, moist sites.	Excellent	DS, NS, CS	Good	Rapid	Fair	Adapted to disturbed sites, suited to moist but not saturated soils.
Artemisia tripartita Tall threetip sagebrush	Asp.-Mtn.B.	Well-drained soils, moist sites.	Excellent	DS, NS, CS	Excellent	Rapid	Fair	Well suited to eroded exposed soils, spreads quickly.
Atriplex canescens Fourwing saltbush	Mtn.B.-V	Well-drained soils, frequent flooding and shallow water table.	Good	DS, NS	Excellent	Rapid	Good	Useful for well-drained and disturbed soils.
Atriplex gardneri Gardner saltbush	SDS-V	Semiarid deserts. Withstands seasonal flooding, and alternating wet/dry period.	Fair	DS, NS, CS	Fair	Moderate	Fair	Adapted to arid sites subjected to seasonal saturated soils.
Betula occidentalis occidentalis Water birch	SF-Mtn.B.	Stream edges.	Good	NS	Excellent	Rapid	Excellent	Establishes well by transplanting, adapted to streambanks and bogs.
Ceanothus sanguineus Redstem ceanothus	SF-PP	Moist soils, seeps, well-drained soils.	Good	DS, NS, CS	Excellent	Rapid	Excellent	Not adapted to saturated soils but useful in planting disturbed streambanks.
Chrysothamnus nauseosus consimilis Thinleaf rubber rabbitbrush	Sage-V	Well-drained soils, sites occasionally flooded.	Good	DS, NS, CS	Excellent	Moderate	Fair	Suited to heavy saturated soils.
Cornus stolonifera stolonifera Redosier dogwood	SF-Mtn.B.	Stream edges and well-drained soils.	Good	DS, NS, CS, RC	Excellent	Rapid	Excellent	Easy to grow and establish, useful for disturbed sites, requires fresh aerated water.
Crataegus douglasii Douglas hawthorn	Asp.-Sage	Stream edges and well-drained soils.	Good	NS	Fair	Slow	Good	Slow growing, but well suited to disturbed streambanks.
Elaeagnus angustifolia Russian olive	Mtn.B.-V	Stream edges, seeps, flooded sites, and well-drained soils.	Excellent	DS, NS	Excellent	Rapid	Good	Easy to establish, can become weedy.
Elaeagnus commutata Silverberry	PJ-V	Stream edges and well-drained soils.	Excellent	NS, CS	Excellent	Rapid	Good	Easily established, grows rapidly, adapted to harsh sites.
Holodiscus discolor Rockspirea	SF-Mtn.B.	Well-drained and moist soils, occasional seeps.	Good	NC, CS	Fair	Moderate	Good	Erratic establishment, but suited to disturbed sites.
Lonicera tatarica Tatarian honeysuckle	Mtn.B.-Sage	Well-drained and moist soils, occasional wet sites.	Excellent	NC, CS, DS	Excellent	Rapid	Good	Easily established, provides immediate cover, well adapted to different soil conditions.

Pachistima myrsinites Myrtle pachistima	SF-Asp.	Moist soils and seeps, requires some shade.	Fair	NS, CS	Fair	Slow	Good	Common to upland slopes, not well adapted to disturbances.
Physocarpus malvaceus Mallow ninebark	SF-Asp.	Moist and well-drained soils.	Fair	NS, CS	Fair	Moderate	Good	Requires good sites.
Populus angustifolia Narrowleaf cottonwood	Asp.-Sage	Well-drained and wet sites, edges of streams, ponds, bogs.	Good	NS, CS, RC	Good	Rapid	Good	Establishes easily, grows rapidly.
Populus fremontii fremontii Fremont cottonwood	Mtn.B.-V	Moist soils, seeps, frequently wet sites.	Good	NS, CS, RC	Good	Rapid	Good	Establishes easily, grows rapidly, furnishes good cover.
Populus tremuloides Quaking aspen	SF-Asp.	Well-drained and moist soils, occasionally occurs at edges of streams.	Fair	NS, CS, RC	Good	Rapid	Good	Considerable ecotypic differences, not well suited to highly disturbed sites, occupies wide range of moisture.
Potentilla fruticosa Bush cinquefoil	Alp.-PP	Stream edges, wet meadows.	Excellent	NS, CS	Good	Moderate	Excellent	Valuable species for riparian disturbances, establishes well and provides excellent site stability.
Prunus virginiana melanocarpa Black chokecherry	SF-PJ	Well-drained, moist soils, occasionally occurs at streams' edges.	Fair	NS, CS, RC	Good	Moderate	Good	Widely adapted, larger transplant stock establishes and grows rapidly.
Rhamnus purshiana Cascara buckthorn	SF-PP	Moist soils, frequently wet sites.	Fair	NS, CS	Fair	Moderate	Good	Limited plantings, plants perform well on disturbed sites.
Ribes aureum Golden current	Asp.-Sage	Well-drained moist sites.	Excellent	NS, CS	Excellent	Excellent	Good	Widely adapted, easily established, excellent site stablity.
Rosa woodsii Woods rose	Asp.-Mtn.B.	Moist and well-drained soils, seeps and frequently streambanks.	Excellent	NS, CS, W, RC	Excellent	Moderate	Good	Widely adapted, easily established, excellent site stability, principal species for riparian disturbances.
Rubus spp.	Asp.-PP	Well-drained soils, frequently wet sites	Excellent	NS, CS, W, RC	Excellent	Moderate	Good	Well adapted to eroded sites, limited range of distribution.
Salix (see table 29)								
Sambucus racemosa pubens microbotrys Red elder	Asp.-PP	Moist sites, occasional seeps and streambanks.	Good	NS, CS	Fair	Moderate	Good	Adapted to restricted sites, establishes slowly on disturbed sites.
Sarcobatus vermiculatus Black greasewood	SDS-V	Sites with shallow water tables, occasionally flooded sites.	Good	NS, W	Fair	Slow	Good	Difficult to establish, well adapted to valley bottoms and salty soils.
Shepherdia argentea Silver buffaloberry	Mtn.B-V	Well-drained sites, edges of streams and ponds.	Good	NS	Good	Moderate	Good	Adapted to valley bottoms and saline soils.
Sorbus scopulina scopulina Green's mountain ash	SF-Asp.	Moist soils, ocassional seeps and stream bottoms.	Fair	NS, CS	Fair	Slow	Good	Not well adapted to disturbed soils, establishes slowly.
Symphoricarpos albus Common snowberry	SF-Asp.	Moist sites and well-drained soils.	Good	NS, CS, W, RC	Fair	Moderate	Excellent	Not well suited to extreme disturbed soils, once established grows well, plant large 1-0 or 2-0 stock.
Symphoricarpos occidentalis Western snowberry	SF-Mtn.B.	Moist sites, occasionally streambanks and valley bottoms.	Good	NS, CS, W, RC	Fair	Slow	Excellent	Plants not well adapted to disturbed soils, provides excellent stability and spreads well.
Symphoricarpos oreophilus Mountain snowberry	Asp.-Sage	Well-drained soils, edges of streams.	Good	NS, CS, W, RC	Fair	Slow	Excellent	Plants not well adapted to disturbed soils, provides excellent stability and spreads well.

---

[1] Alp. = alpine; SF = spruce-fir; Asp. = aspen; PP = ponderosa pine; Mtn.B. = mountainbrush; PJ = pinyon-juniper; Sage = big sagebrush; SDS = salt desert shrub; V = valley bottoms.
[2] DS = direct seeding; RC = rooted cuttings; NS = nursery-grown seedling; CS = container-grown seedling; W = wilding.

Table 29—Areas of occurrence of several willow species useful in riparian revegetation. Scientific names from Goodrich (1983).

Species	Areas of adaptation		Origin of roots	Prevalence of roots	Period required for:		Comments
	Zones	Habitat			Root formation	Stem formation	
					- - - - - - - *Days* - - - - - - -		
Salix amygdaloides Peachleaf willow	Aspen— big sagebrush	Stream edges, pond margins, soils saturated seasonally.	Callus cut	Moderate	10-20	10	Moderate rooting capabilities
Salix bebbiana Bebb willow	Spruce-fir— aspen	Edges of streams, occasionally well-drained soils.	Roots throughout entire length of stem	Moderate	10	10-20	Roots freely
Salix boothii	Aspen— sagebrush	Stream edges and standing water, confined to wet soils.	Roots mostly at lower one-third of stem	Abundant	10-15	10-15	Roots freely
Salix brachycarpa Barrenground willow	Subalpine— spruce-fir	Wet sites and well-drained soils.	Roots throughout entire length of stem	Abundant	15-20	15-25	Roots freely
Salix drummondiana Drummond willow	Spruce-fir— upper sagebrush	Edges of streams and ponds.	Roots throughout entire length of stem	Abundant	10	10	Roots freely
Salix exigua Sandbar willow	Spruce-fir— sagebrush	Edges of streams, wet sites, sometimes well-drained soils.	Roots throughout entire length of stem	Moderate	10-15	10	Easily rooted
Salix geyeriana Geyer willow	Subalpine—aspen— upper sagebrush	Edges of streams, frequent wet meadows.	Roots throughout entire length of stem	Few to moderate	10	10-15	Fair rooting capabilities
Salix glauca Grayleaf willow	Subalpine— spruce-fir	Wet and dry sites, widely distributed, occupies seeps and edges of snowbanks.	Roots throughout entire length of stem	Few to moderate	10	10	Requires special treatment to root
Salix lasiandra Pacific willow	Aspen— upper sagebrush	Wet soils, edges of streams and ponds.	Roots throughout entire length of stem	Abundant	10	10-15	Easily rooted
Salix lasiolepis Arroyo willow	Aspen— mountainbrush	Restricted to stream edges.	Callus and lower one-third of stem	Few to many	10	10	Erratic rooting habits
Salix lutea Shining willow	Aspen— sagebrush	Mostly along streams, may occur on sites that remain dry for short periods.	Entire stem section, most abundant at lower one-third	Moderate	10	10	Roots easily
Salix planifolia Tealeaf willow	Subalpine— aspen	Wet sites, edges of streams, wet meadows.	Roots throughout entire length of stem	Few to moderate	10	10-15	Fair rooting capabilities
Salix scouleriana Scouler willow	Spruce-fir— aspen	Well-drained soils, forest understory.	Callus cut	Moderate	10-15	10-15	Requires special treatment to root
Salix wolfii Wolf willow	Spruce-fir— aspen	Stream edges and ponds.	Roots throughout entire length of stem	Few to moderate	10-15	10-15	Erratic rooting

Snow and Vince (1984) conclude from reciprocal transplanting that dominant perennial species of salt marsh sites have a broad tolerance and are able to grow in diverse habitats. However, plants are confined to restricted areas due to dispersal limitations and the inability of propagules to establish. Seedlings are often less tolerant of environmental stress than are mature plants (Pearson and others 1966). Similar conditions apply to woody plantings. Willows and other shrubs are widely adapted to diverse sites, including seriously disrupted conditions (McCluskey and others 1983). However, young plantings are difficult to establish and only the most vigorous stock should be planted. Neiland and others (1981) conclude that planting success of unrooted cuttings of *Salix* is unpredictable and depends on site conditions and yearly climatic variables. Unrooted stem cuttings frequently fail to establish (Holloway and Zasada 1979).

Stem cuttings can be obtained from plants growing on wildland sites. Collections should be taken from stock adapted to the planting areas. Clonal differences, age of the plant, and yearly growing conditions affect the propagation capabilities of the cuttings (Doran 1957).

Cuttings should be taken in the spring or fall when plants are dormant. Densmore and Zasada (1978) found that spring collections survived nearly four times better than fall collections of the same species. Cuttings should be taken of 2- to 4-year-old wood, and stems 0.4 inch or larger in diameter survive much better than smaller dimensions. The age and size of the stem are of less importance to readily rooted willow species than to poorly rooted selections (Chmelar 1974). Larger and older wood is required to propagate poorly rooted species.

Stem cuttings should be 12 to 20 inches in length. Shorter segments may survive if planted under ideal conditions. However, Neiland and others (1981) found that cuttings with at least an 8-inch belowground length and a 7-inch aboveground portion produced twice the amount of growth the first year as did cuttings of 4 inches/3 inches. Longer stems have a greater rooting surface to extract soil moisture and a higher amount of carbohydrates.

After collection, cuttings should be bundled in groups of 50 or 100 sections and treated with a fungicide (Doran 1957) by dipping the entire stem into a prepared solution or powder. Numerous fungicides are available. Stems should be dried and then stored for future plantings.

Hormones can be used to induce rooting. Only the most difficult species require such treatment, and species with preformed root primordia should not be treated. The hormone can be applied by dipping the base of the cutting in either a powder or mixed solution. Indolebutyric acid is the most effective rooting compound because it not only increases rooting of the more difficult species but hastens rooting and lengthens the growing season (Doran 1957).

Cuttings can be stored for extended periods by enclosing the moistened bundles in plastic bags or other moist media and protecting from dehydration. The cuttings can then either be frozen and stored in coolers or maintained at temperatures slightly above freezing. Prior to planting, frozen cuttings should be chilled at 41 °F for 2 to 3 weeks to break dormancy.

Field plantings of unrooted cuttings or nursery-grown seedlings can be established in prepared beds. Planting sites should be cleared of competitive vegetation, and compact soils should be loosened to accommodate transplanting. Willows are sensitive to competition and light, and dense tall grasses reduce the survival of the transplants (Neiland and others 1981). Plant competition is much more critical to the survival of unrooted cuttings than to the survival of rooted stock. If sites are properly prepared, the majority of transplant losses occur the first year. If the understory competition is not controlled, losses can be expected for 1 to 3 years.

Understory herbs can be eliminated or reduced in density (1) by mechanical scalping or clearing of the surface soil and associated vegetation or (2) by chemical control. Transplants can be selectively placed in clearings or openings where competition is low, but interplanting into existing herblands is not achievable unless the competition can be reduced.

Clearings or scalps of 20 to 30 inches are normally required to effectively reduce competition during establishment. Mechanical scalping usually is not effective in controlling rhizomatous vegetation. Resprouting or rerooting occurs quickly and is detrimental to transplant survival.

Planting rooted or unrooted stock in areas with a high water table is not advised. Although species of willow differ in their adaptability to soil inundation, flooding can reduce growth because of an imbalance of hormones, uptake of water and nutrients, and the disruption of carbohydrate relations (Kozlowski 1984). Transplants should not be placed directly onto water-logged soils or into the stream. Better rooting occurs if transplants are placed in moist but not saturated soils.

Fertilization is often used to stimulate growth of the transplant. Fertilizers can be beneficial if growth of herbaceous plants is not stimulated (Neiland and others 1981) because increased growth of the herbs is detrimental to shrub survival. Fertilizer tablets can be used and should be placed in the planting hole or in proximity of the planted stock. Surface application should be avoided as a means of fertilizing the transplant because grasses also respond to the treatment. Increased growth of the shrub transplant can be expected for 2 to 3 years after fertilization if slow-release tablets are used.

Hansen and Phipps (1983) found that warming and soaking of poplar cuttings accelerated growth of transplants. Prerooting of willow cuttings has also improved survival and enhanced growth of field plantings. Prerooting can be accomplished by growing the willow cuttings under greenhouse conditions for a short period and then field planting the newly rooted stem. The cutting is allowed to form roots that are 0.8 to 1.2 inches in length. Once roots are formed, the cutting is hardened-off and field planted. Plants must be properly hardened or survival is significantly diminished.

Field survival of stem cuttings can be enhanced by correct planting depth. A stem cutting of approximately 20 inches in length should be planted to a depth of about 12 inches, leaving an 8-inch section exposed. Longer aboveground stems are subjected to excessive drying. If high air temperatures are expected, stems should be placed deeper in the soil. Dehydration can also be prevented by dipping or applying antitranspirants to the stems prior to planting. Film-forming antitranspirants are recommended for treating transplant stock (Kozlowski and Davis 1975). Different antitranspirant compounds are available and effective if applied at the proper rate (Davis and Kozlowski 1974).

REFERENCES

Aldon, E. F. Survival of three grass species after inundation. Research Note RM-165. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 2 p.

Alley, H. P.; Gale, A. F.; Humburg, N. E. Wyoming weed control guide, 1978. Wyoming Extension Bulletin 442R. Laramie, WY: Wyoming Agricultural Extension Service; 1978. 53 p.

Anderson, B. W.; Ohmart, R. D.; Hunter, W. C. Quantifying variables for classifying desert riparian vegetation. In: Moir, W. H.; Hendzel, L., tech. coords. Workshop on southwestern habitat types: Proceedings; 1983 April 6-8; Albuquerque, NM. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region; 1984: 32-34.

Arizona Citizen. April 22, 1871.

Armour, C. L.; Burnham, K. P.; Platts, W. S. Field methods and statistical analyses for monitoring small salmonid streams. FWS/OBS-83/33. Washington, DC: U.S. Fish and Wildlife Service; 1983. 200 p.

Arnold, John F. Idaho batholith source book. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1975. 342 p. Unpublished report.

Back, H. L.; Alder, F. E.; Gibbs, B. G. An evaluation of an electronic instrument for pasture yield estimation. Part 2. Use with double sampling for pasture yield estimation. Journal of British Grasslands Society. 24: 168-172; 1968.

Baker, C. O. The impacts of log jam removal on fish populations and stream habitat in western Oregon. Corvallis, OR: Oregon State University; 1979. 86 p. Thesis.

Baskerville, G. L. Use of logarithmic regression in the estimation of plant biomass. Canadian Journal of Forest Research. 2(1): 49-53; 1972.

Bilby, R. E.; Likens, G. E. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology. 61: 1107-1113; 1980.

Bishop, D. M. Big Creek photo-study of logs and debris in the stream. Second Interim Report-1967. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region; 1968. 9 p.

Blake, O. Timber down the hill. Corvallis, OR: Oregon State University Library, private collection; 1971. 85 p.

Bloom, A. L. Geomorphology: a systematic analysis of late Cenozoic landforms. Englewood Cliffs, NJ: Prentice-Hall; 1978. 510 p.

Bowen, W. A. Migration and settlement on a far western frontier: Oregon to 1850. Berkeley, CA: University of California; 1972. Ph.D. thesis.

Bridges, J. B. Definition of the law governing the use of driving streams. In: Proceedings of the Pacific logging congress, second annual session; 1910 July 21-23; Portland, OR: 1910: 50-51.

Brown, N. C. Logging-transportation: the principles and methods of log transportation in the U.S. and Canada. New York: John Wiley and Sons; 1936. 327 p.

Bryant, M. D. Evolution of large, organic debris after timber harvest: Maybeso Creek 1949-1978. General Technical Report PNW-101. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 30 p.

Bryant, M. D. Organic debris in salmonid habitat in southeast Alaska: measurement and effects. In: Armantrout, N. B., ed. Acquisition and utilization of aquatic habitat inventory information: Proceedings of a symposium; 1981 October 28-30; Portland, OR. Portland, OR: Western Division American Fisheries Society; 1981: 259-265.

Bryant, M. D. The role and management of woody debris in West Coast salmonid nursery streams. North American Journal of Fisheries Management. 3: 322-330; 1983.

Buchanan, I. L. Lumbering and logging in the Puget Sound Region in territorial days. Pacific Northwest Quarterly. 27: 34-53; 1936.

Burke, C. J. Historical fires in the central western Cascades, Oregon. Corvallis, OR: Oregon State University; 1979. M.S. thesis.

Carlson, M. C. Nodal adventitious roots in willow stems of different ages. American Journal of Botany. 37: 555-561; 1950.

Carpenter, L. H.; Wallmo, D. C.; Morris, M. J. Effect of woody stems on estimating herbage weights with a capacitance meter. Journal of Range Management. 26: 151-152; 1973.

Chambers, J. L.; Brown, R. W. Methods for vegetation sampling and analysis on revegetated mixed lands. General Technical Report INT-151. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 57 p.

Chmelar, J. Propagation of willows by cuttings. New Zealand Journal of Forestry Science. 4: 185-190; 1974.

Cluff, G. J.; Evans, R. A.; Young, J. A. Desert saltgrass seed germination and seedbed ecology. Journal of Range Management. 36(4): 419-422; 1983.

Cochran, W. G. Sampling techniques. 2d ed. New York: John Wiley and Sons; 1963. 413 p.

Colwell, R. N., ed. Manual of remote sensing. Vol. II. Falls Church, VA: American Society of Photogrammetry; 1983. 1232 p.

Cords, H. P.; Artz, J. L. Rangeland, irrigated pastures, and meadows—weed control recommendations. Circular 148. Rev. Reno, NV: Nevada Agricultural Extension Service; 1976. 4 p.

Council of Agricultural Science and Technology. Livestock grazing on federal lands in the 11 western states. Journal of Range Management. 27(3): 174-181; 1974.

Cowardin, L. M.; Carter, V.; Golet, F. C.; LaRoe, E. T. Classification of wetlands and deepwater habitats of the United States. Publication FWS/OBS-79/31. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services; 1979. 103 p.

Cox, T. R. Mills and markets: a history of the Pacific Coast lumber industry to 1900. Seattle, WA: University of Washington Press; 1974. 396 p.

Cummins, K. W. Trophic relations of aquatic insects. Annual Review of Entomology. 18: 183-206; 1973.

Cummins, K. W. Structure and function of stream ecosystems. BioScience. 24: 631-641; 1974.

Cummins, K. W.; Klug, M. J.; Ward, G. M.; Spengler, G. L.; Speaker, R. W.; Ovink, R. W.; Mahan, D. C.; Petersen, R. C. Trends in particulate organic matter fluxes, community processes, and macroinvertebrate functional groups along a Great Lakes drainage basin river continuum. Verhandlunger Internationale Vereinigung für Theoretische und Angewandte Limnologie. 21: 841-849; 1981.

Cummins, K. W.; Merritt, R. W. Ecology and distribution of aquatic insects. In: Merritt, R. W.; Cummins, K. W., eds. An introduction to the aquatic insects. 2d ed. Dubuque, IA: Kendall/Hunt Publishing; 1984: 59-65.

Cummins, K. W.; Minshall, G. W.; Sedell, J. R.; Cushing, C. E.; Petersen, R. C. Stream ecosystem theory. Verhandlungen Internationale Vereinigung für Theoretische und Angewandte Limnologie. 22; 1984.

Cuplin, P. Remote sensing streams. In: Proceedings of the international symposium on remote sensing of observation and inventory of earth resources and the endangered environment; 1978 July 2-8; Freiburg, Federal Republic of Germany. Vol. III. 2391 p. International Archives of Photogrammetry Vol. XXII-7.

Currie, P. O.; Morris, M. J.; Neal, D. L. Uses and capabilities of electronic capacitance instruments for estimating standing herbage. Part 2. Sown ranges. Journal of the British Grasslands Society. 28: 155-160; 1973.

Dahlgreen, A. K.; Ryker, R. A.; Johnson, D. L. Snow cache seedling storage: successful systems. General Technical Report INT-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 12 p.

Davis, W. J.; Kozlowski, T. T. Short- and long-term effects of antitranspirants on water relations and photosynthesis of woody plants. Journal of the American Society for Horticultural Science. 99(4): 297-304; 1974.

Densmore, R.; Zasada, J. C. Rooting potential of Alaskan willow cuttings. Canadian Journal of Forest Research. 8: 477-479; 1978.

DeVries, P. G. Live intersect sampling theory. In: Cormack, R. M.; Patil, G. P.; Robson, O. S., eds. Sampling biological populations. Statistical Ecology Series. Vol. 5. Fairland, MD: International Co-operative Publishing House; 1979: 3-63.

Dicken, S. N.; Dicken, E. F. The making of Oregon: a study in historical geography. Vol. I. Portland, OR: Oregon Historical Society; 1979. 207 p.

Doran, W. L. Propagation of woody plants by cuttings. Experiment Station Bulletin 491. Amhurst, MA: University of Massachusetts, College of Agriculture; 1957. 99 p.

Forman, T. T.; Russell, E. W. B. Evaluation of historical data in ecology. Bulletin of the Ecological Society of America. 64: 5-7; 1983.

Frick, E. Library research guide to history. Library Research Guides, Series 4. Ann Arbor, MI: Pierian Press; 1980. 86 p.

Frink, M.; Jackson, W. T.; Spring, A. W. When grass was king. Boulder, CO: University of Colorado Press; 1956. 465 p.

Froehlich, H. A.; McGreer, D.; Sedell, J. R. Natural debris within the stream environment. US/IBP Coniferous Forest Biome, Internal Report 96. Seattle, WA: College of Forest Resources, University of Washington; 1972. 16 p.

Furnival, G. M. An index for comparing equations used in constructing volume tables. Forest Science. 7: 337-341; 1961.

Goodrich, Sherel. Utah flora: Salicaceae. Great Basin Naturalist. 43(4): 531-550; 1983.

Griffiths, D. Forage conditions on the northern border of the Great Basin. Bulletin 15. Washington, DC: U.S. Department of Agriculture, Bureau of Plant Industry; 1902. 39 p.

Griffiths, D. Forage conditions and problems in eastern Washington, eastern Oregon, northeastern California, and northwestern Nevada. Bulletin 38. Washington, DC: U.S. Department of Agriculture, Bureau of Plant Industry; 1903. 57 p.

Gruell, G. E. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume 1—Photographic record and analysis. Research Paper INT-235. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 207 p.

Haissig, B. W. Preformed adventitious root initiation in brittle willows grown in a controlled environment. Canadian Journal of Botany. 4(2): 299-310; 1970.

Hansen, E. A.; Phipps, H. M. Effects of soil moisture tension and preplant treatment on early growth of hybrid *Populus* hardwood cuttings. Canadian Journal of Forest Research. 13: 458-464; 1983.

Hastings, J. R. Vegetation change and arroyo cutting in southeastern Arizona. Journal of the Arizona Academy of Science. 1: 60-67; 1959.

Hastings, J. R.; Turner, R. M. The changing mile: an ecological study of vegetation change with time in the lower mile on an arid and semiarid region. Tucson, AZ: University of Arizona Press; 1965. 317 p.

Hawkins, C. P.; Murphy, M. L.; Anderson, N. H. Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade range streams of Oregon. Ecology. 63: 1840-1856; 1982.

Hawkins, C. P.; Sedell, J. R. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology. 62: 387-397; 1981.

Heebner, C. F.; Bergener, M. J. Red alder: a bibliography with abstracts. General Technical Report PNW-161. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 186 p.

Heikes, P. E. Colorado weed control handbook. Fort Collins, CO: Colorado State University; 1978. Mimeographed (updated looseleaf).

Holloway, P.; Zasada, J. Vegetative propagation of 11 common Alaska woody plants. General Technical Report PNW-334. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 12 p.

Horton, J. S. Trees and shrubs for erosion control on southern California mountains. Sacramento, CA: California Department of Natural Resources, Division of Forestry; 1949. 71 p.

Jensen, L. A.; Evans, J. O.; Anderson, J. L.; Hamson, A. R.; Parker, K. G. Chemical weed control guide, Utah, 1980 and 1981 addendum. Revised Circular 301. Logan, UT: Utah Agricultural Extension Service; 1981 (rev.). 113 plus 12 p.

Jensen, S. E. Soils investigation of riparian communities of East Smiths Fork and Henrys Fork Drainages, North Slope Uinta Mountains, Utah. 1981. Report to U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 35 p.

Jensen, S. E. Evaluation of the effect of water retainment upon down drainage wetlands in the Upper Bear River drainage. 1984. Unpublished report on file at: White Horse Associates, Smithfield, UT. 50 p.

Jensen, S. E.; Tuhy, J. S. Riparian classification for the Upper Salmon/Middle Fork Salmon Rivers, Idaho. 1982. Report to U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 195 p.

Johannessen, C. L.; Davenport, W. A.; Millet, A.; McWilliams, S. The vegetation of the Willamette Valley. Annual Association of American Geographers. 61: 286-302; 1970.

Kangus, P. Studies of succession, landscape, and phosphate mining. Gainesville, FL: University of Florida, Center for Wetlands; 1978. 23 p. Unpublished manuscript.

Kauffman, J. B.; Krueger, W. C. Livestock impacts on riparian ecosystems and streamside management implications. . . a review. Journal of Range Management. 37(5): 430-438; 1984.

Keller, E. A.; MacDonald, A. Large organic debris and anadromous fish habitat in the coastal redwood environment: the hydrologic system. Technical Completion Report, Project No. B-213-CAL and Project UCAL-WRC-W-584. Davis, CA: University of California, California Water Resources Center; 1984. 18 p.

Keller, E. A.; Talley, T. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes. 4: 361-380; 1979.

Kish, L. Survey sampling. New York: John Wiley & Sons; 1965. 643 p.

Kozlowski, T. T. Plant responses to flooding of soil. BioScience. 34: 162-167; 1984.

Kozlowski, T. T.; Davis, W. J. Control of water balance in transplanted trees. Journal of Arboriculture. 1(1): 1-10; 1975.

Lammel, R. F. Natural debris and logging residue within the stream environment. Corvallis, OR: Oregon State University; 1972. 49 p. M.S. thesis.

Landis, T. D.; Simonich, E. J. Producing native plants as container seedlings. In: Murphy, P. M., compiler. The challenge of producing native plants for the Intermountain area: Proceedings; Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984: 16-25.

Langbein, W. G.; Iseri, K. T. General introduction and hydrologic definitions. Geological Survey Water Supply Paper 1541-A. Washington, DC: U.S. Department of the Interior; 1960. 29 p.

Lemmon, P. E. A new instrument for measuring forest overstory density. Journal of Forestry. 55: 667-669; 1956a.

Lemmon, P. E. A spherical densiometer for estimating forest overstory density. Forest Science. 2: 314-320; 1956b.

Leopold, S. A. Ecosystem deterioration under multiple use. In: Proceedings—wild trout management symposium. Denver, CO: U.S. Department of the Interior, Fish and Wildlife Service; 1974: 96-98.

Lewis, M. E. *Carex*—its distribution and importance in Utah. Science Bulletin Biological Series—Vol. 1, No. 11. Provo, UT: Brigham Young University; 1958. 43 p.

Lienkaemper, G. W.; Swanson, F. J. Changes in large organic debris in forested streams, western Oregon. In: Abstracts with programs, Cordilleran Section, Geological Society of America. 12(3); 1980. 116 p.

Long, S. G.; Burrell, J. K.; Laurenson, N. M.; Nyenhuis, J. H. Manual of revegetation techniques. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center; 1984. 145 p.

Lowrance, R.; Todd, R.; Fail, J., Jr.; Hendrickson, A., Jr.; Leonard, R.; Asmussen, L. Riparian forests as nutrient filters in agricultural watersheds. BioScience. 34: 374-377; 1984.

Marshall, K.; Romesburg, H. C. CLUSTAR and CLUSTID - programs for hierarchical cluster and analysis. In: Henderson, J. A.; Davis, L. S.; Ryberg, F. M. ECOSYM: a classification and information system for wildland resource management. Logan, UT: Utah State University; 1977. 65 p.

McCluskey, C. D.; Brown, J.; Bornholdt, D.; Duff, D. A.; Winward, A. H. Willow planting for riparian habitat improvement. Technical Note 363. Denver, CO: U.S. Department of the Interior, Bureau of Land Management; 1983. 21 p.

McDonald, S. E.; Boyd, R. J.; Sears, D. E. Lifting, storage, planting practices influence growth of conifer seedlings in the Northern Rockies. Research Paper INT-300. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 12 p.

Meehan, W. R.; Platts, W. S. Livestock grazing and the aquatic environment. Journal of Soil and Water Conservation. 33(6): 274-278; 1978.

Megahan, W. F.; Kidd, W. J. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. Journal of Forestry. 70(3): 136-141; 1972.

Merritt, R. W.; Cummins, K. W., eds. An introduction to the aquatic insects. 2d ed. Dubuque, IA: Kendall/Hunt Publishing Co.; 1984. 722 p.

Meyer, M.; Batson, F.; Whitmer, D. Helicopter-borne 35 mm aerial photography applications to range and riparian studies. St. Paul, MN: University of Minnesota, Remote Sensing Laboratory; 1982. 80 p.

Minshall, G. W. Structure and temporal variations of the benthic macroinvertebrate community inhabiting Mink Creek, Idaho, U.S.A., a 3rd order Rocky Mountain stream. Journal of Freshwater Ecology. 1: 13-26; 1981.

Minshall, G. W.; Cummins, K. W.; Petersen, R. C.; Cushing, C. E.; Bruns, D. A.; Sedell, J. R.; Vannote, R. L. Developments in stream ecosystem theory. Canadian Journal of Fisheries and Aquatic Sciences. 42: 1045-1055; 1985.

Minshall, G. W.; Petersen, R. C.; Cummins, K. W.; Bott, T. L.; Sedell, J. R.; Cushing, C. E.; Vannote, R. L. Interbiome comparison of stream ecosystem dynamics. Ecological Monographs. 51: 1-25; 1983.

Molles, M. C., Jr. Trichopteran communities of streams associated with aspen and conifer forests: long-term structural change. Ecology. 63: 1-6; 1982.

Monsen, S. B. Plants for revegetation of riparian sites within the Intermountain Region. In: Monsen, S. B.; Shaw, N., compilers. Managing Intermountain rangelands—improvement of range and wildlife habitats: Proceedings; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. General Technical Report INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983: 83-89.

Morris, M. J.; Johnson, K. L.; Neal, D. L. Sampling shrub ranges with an electronic capacitance instrument. Journal of Range Management. 29: 78-81; 1976.

Mueller-Dombois, D.; Ellenberg, H. Aims and methods of vegetation ecology. New York: John Wiley and Sons; 1974. 547 p.

Naiman, R. J. Characteristics of sediment and organic carbon export from pristine boreal forest watersheds. Canadian Journal of Fisheries and Aquatic Sciences. 39: 1699-1718; 1982.

Neal, D. L.; Neal, J. L. Uses and capabilities of electronic capacitance instruments for estimating standing herbage. Part 1. History and development. Journal of the British Grassland Society. 28: 81-89; 1973.

Neal, D. L.; Currie, P. O.; Morris, M. J. Sampling herbaceous vegetation with an electronic capacitance instrument. Journal of Range Management. 29: 74-77; 1976.

Neiland, B. J.; Zasada, J.; Densmore, R.; Masters, M. A.; Moore, N. Investigations of techniques for large-scale reintroduction of willows in Arctic Alaska. Final report to Alyeska Pipeline Service Company. Fairbanks, AK: University of Alaska, School of Agriculture and Land Resources Management; 1981. 448 p.

Nelson, R. L.; Platts, W. S.; Graham, C. K. Relative suitabilities of linear and logarithmic regression model in electronic capacitance meter analysis of riparian vegetation. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; [in press].

Newbold, J. D.; Erman, D. C.; Roby, K. B. Effects of logging on macroinvertebrates in streams with and without buffer strips. Canadian Journal of Fisheries and Aquatic Sciences. 37: 1076-1085; 1980.

Norton, B. E.; Tuhy, J. S.; Jensen, S. Riparian community classification for the Greys River, Wyoming. Logan, UT: Utah State University, Department of Range Science; 1981.

190 p. [Report to U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT.]

Odum, E. P. Fundamentals of ecology. 3d ed. Philadelphia, PA: W. B. Saunders Company; 1971. 574 p.

Ohmart, R. D.; Deason, W. O.; Burke, C. A riparian case history: the Colorado River. In: Johnson, R. R.; Jones, D. E., tech. coords. Importance, preservation and management of riparian habitat: a symposium. General Technical Report RM-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977: 35-57.

Owston, P. W.; Stein, W. I. Production and use of container seedlings in the West. In: Loucks, W. L., ed. Proceedings of meetings; August 1977. Manhattan, KS: Intermountain Nurserymen's Association; 1977: 117-125.

Pearson, G. A.; Ayers, A. D.; Ederhard, D. C. Relative salt tolerance of rice during germination and early seedling development. Soil Science. 201: 151-156; 1966.

Petersen, L. A.; Phipps, H. M. Water soaking pretreatment improves rooting and early survival of hardwood cuttings of some *Populus* clones. Tree Planters' Notes. 27(1): 12-22; 1976.

Phipps, H. M.; Belton, D. A.; Netzer, D. A. Propagating cuttings of some *Populus* clones for tree planting. Plant Propagation. 23: 8-11; 1977.

Platts, W. S. Effects of sheep grazing on a riparian-stream environment. Research Note INT-307. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981a. 6 p.

Platts, W. S. Influence of forest and rangeland management on anadromous fish habitat in western North America. Part 7. Effects of livestock grazing. General Technical Report PNW-124. Meehan, W., tech. ed. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981b. 25 p.

Platts, W. S.; Megahan, W. F.; Minshall, G. W. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 70 p.

Platts, W. S.; Nelson, R. L. The electronic capacitance meter: a tool for evaluating riparian-fishery habitat. North American Journal of Fisheries Management. 3: 219-227; 1983.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. Restoring big game range in Utah. Publication 68-3. Salt Lake City, UT: Utah Division of Fish and Game; 1968. 183 p.

Poulton, C. E.; Tisdale, E. W. A quantitative method for the description and classification of range vegetation. Journal of Range Management. 14: 13-21; 1961.

Quigley, T. M. Estimating contribution of overstory vegetation to stream surface shade. Wildlife Society Bulletin. 9(1): 22-27; 1981.

Ray, G. A.; Megahan, W. F. Measuring cross section using a sag tape: a generalized procedure. General Technical Report INT-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978. 12 p.

Rector, W. G. From woods to sawmill: transportation problems in logging. Agriculture History. 23: 239-244; 1949.

Rector, W. G. Log transportation in the Lake States lumber industry 1840-1918. Glendale, CA: Arthur H. Clark Co.; 1953. 352 p.

Ree, W. O. Effect of seepage flow on reed canarygrass and its ability to protect waterways. ARS-S-154. Stillwater, OK: U.S. Department of Agriculture, Agricultural Research Service, Water Conservation Structures Laboratory; 1976. 8 p.

Reese, G. A.; Bayn, R. L.; West, N. E. Evaluation of double-sampling estimators of subalpine herbage production. Journal of Range Management. 33(4): 300-306; 1980.

Sands, A.; Howe, G. An overview of riparian forests in California: their ecology and conservation. In: Johnson, R. R.; Jones, D. E., tech. coords. Importance, preservation and management of riparian habitat: a symposium. General Technical Report RM-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977: 98-115.

Scheaffer, R. L.; Mendenhall, W.; Ott, L. Elementary survey sampling. 2d ed. Boston: Duxbury Press; 1979. 278 p.

Secretary of War. Index to the reports of Chief of Engineers, U.S. Army, 1866-1912. In: House Documents: Second Session 63rd Congress, 1913-1914. Vol. 20, Part 2. Washington, DC: U.S. Government Printing Office; 1915. 350 p.

Sedell, J. R.; Duval, W. S. Water transportation and storage of logs. General Technical Report PNW-186. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Range and Experiment Station; 1985. 68 p. [Meehan, W. R., ed.; Influence of forest and rangeland management on anadromous fish habitat in western North America; pt. 5].

Sedell, J. R.; Everest, F. H.; Swanson, F. J. Fish habitat and streamside management: past and present. In: Proceedings of the Society of American Foresters, annual meeting, 1981 September 27-30; Orlando, FL. Bethesda, MD: Society of American Foresters; 1982: 244-255.

Sedell, J. R.; Froggatt, J. L. Importance of streamside forests to large rivers: the isolation of the Willamette River, Oregon, USA from its floodplain. Verandlungen Internationale Vereinigung für Theoretische und Argewandfe Limnologie. 22: 1828, 1834; 1984.

Sedell, J. R.; Luchessa, K. J. Using the historical record as an aid to salmonid habitat enhancement. In: Armantrout, N. B., ed. Proceedings of a symposium on acquisition and utilization of aquatic habitat inventory information; 1981 October 28-30; Portland, OR. Bethesda, MD: Western Division of American Fisheries Society; 1982: 210-223.

Shafer, D. M.; Ffolliott, P. F.; Patton, D. R. Management of riparian vegetation for southwestern wildlife. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Region; 1982. 20 p.

Shafer, R. J., ed. A guide to historical method. Homewood, IL: Dorsey Press; 1980. 272 p.

Shaw, N. S. Producing bareroot seedlings of native shrubs. In: Murphy, P. M., compiler. The challenge of producing native plants for the Intermountain area: Proceedings; Intermountain Nurserymen's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984: 6-15.

Silvey, L.; Tolle, T.; Elsea, J.; Putnam, W. A channel condition and debris loading evaluation of the Marble Cone fire area. Moscow, ID: University of Idaho, Idaho Cooperative Fishery Research Unit; 1977. 43 p.

Snow, A. A.; Vince, S. W. Plant zonation in an Alaskan salt marsh. Journal of Ecology. 72: 669-684; 1984.

Solar Pathways, Inc. Solar Pathfinder - the energy evaluator. Glenwood Springs, CO: Solar Pathways Incorporated; 1983. 20 p.

Strahler, A. N. Quantitative analysis of watershed geomorphology. Transitions of the American Geophysical Union. 38: 913-920; 1957.

Strichler, G. S. Use of the densiometer to estimate density of forest canopy on permanent sample plots. Research Note INT-180. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1959. 5 p.

Swanson, F. J.; Bryant, M. D.; Lienkaemper, G. W.; Sedell, J. R. Organic debris in small streams, Prince of Wales Island, Southeast Alaska. General Technical Report PNW-166. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1984. 12 p.

Swanson, F. J.; Gregory, S. V.; Sedell, J. R.; Campbell, A. G. Land-water interactions: the riparian zone. In: Edmonds, R. L., ed. Analysis of coniferous forest ecosystems in the western United States. US/IBP Synthesis Series 14. Stroudsburg, PA: Hutchinson Ross Publishing Company; 1982: 267-291.

Talley, T. The effects of geology and large organic debris on stream channel morphology and process for streams flowing through old growth redwood forests in northwestern California. Santa Barbara, CA: University of California; 1980. 273 p. Ph.D. thesis.

Terry, W. S.; Hunter, D. H.; Swindel, B. F. Herbage capacitance meter: an evaluation of its accuracy in Florida rangelands. Journal of Range Management. 34: 240-241; 1981.

Tevis, J. H. Arizona in the '50's. Albuquerque, NM: University of New Mexico Press; 1954. 198 p.

Theurer, F. D.; Voos, K. A.; Miller, W. J. Instream water temperature. Information Paper 16. Fort Collins, CO: U.S. Department of the Interior, Fish and Wildlife Service, IFG and Aquatic System Group; 1984. 400 p.

Thomas, J. W.; Maser, C.; Rodick, J. E. Riparian zones. In: Thomas, J. W., tech. ed. Wildlife habitats in managed forests of the Blue Mountains of Oregon and Washington. Agriculture Handbook 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979: 40-47.

Timberman. Queen of them all was Virginia City: history of lumbering in western Nevada. Timberman. 42: 11-14, 50-62; 1941.

Towle, J. C. Woodland in the Willamette Valley: an historical geography. Eugene, OR: University of Oregon; 1974. 159 p. Ph.D. dissertation.

Trefethen, J. B. The American landscape 1776-1976, two centuries of change. Washington, DC: Wildlife Management Institute; 1976. 91 p.

Triska, F. J.; Cromack, K. The role of wood debris in forests and streams. In: Waring, R. H., ed. Forests: fresh perspectives from ecosystem analysis: Proceedings of the 40th biology colloquium. Corvallis, OR: Oregon State University Press; 1980: 171-189.

Triska, F. J.; Sedell, J. R. Accumulation and processing of fine organic debris. In: Logging debris in streams workshop: Proceedings. Corvallis, OR: Oregon State University; 1975: 35-46.

Tuhy, J. S.; Jensen, S. Riparian community classification for the upper Salmon/Middle Fork Salmon River drainages, Idaho. Report to U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT; 1982. 200 p.

Tuhy, J. S.; Jensen, S. E. Riparian classification for the Greys River, Wyoming. Report to U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT; 1982. 185 p.

U.S. Department of Agriculture, Forest Service. Range environmental analysis handbook. FSH 2209.21. Denver, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1973. Unnumbered pages.

U.S. Department of Agriculture, Forest Service. Range analysis handbook. FSH 2209.21. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1983. Unnumbered pages.

U.S. Department of Agriculture, Forest Service. Pesticide background statements. Volume 1: herbicides. Agriculture Handbook 633. Washington, DC; 1984. Unnumbered pages.

U.S. Department of Agriculture, Soil Conservation Service. Soil taxonomy. Agriculture Handbook 436. Washington, DC; 1975. 754 p.

U.S. Department of Agriculture, Soil Conservation Service. National range handbook. Washington, DC; 1976. Unnumbered pages.

U.S. Department of Agriculture, Soil Conservation Service. Draft soil survey manual. 430-V-SSM. Washington, DC; 1981. 94 p.

U.S. Department of the Interior, Bureau of Land Management. Aerial photography specifications. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, Denver Service Center; 1983. 15 p.

U.S. Supreme Court. The Daniel Ball-U.S. Case 10 Wall 557, 563. Washington, DC: U.S. Supreme Court; 1870.

Vallentine, J. F. Range development and improvements. 2d ed. Provo, UT: Brigham Young University Press; 1980. 545 p.

Vallentine, J. F. The application and use of herbicides for range plant control. In: Monsen, S. B.; Shaw, N., compilers. Managing Intermountain rangelands—improvement of range and wildlife habitats: proceedings; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. General Technical Report INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983: 39-48.

Van Wagner, C. E. The line intersect method in forest fuel sampling. Forest Science. 14(1): 20-26; 1968.

Vannote, R. L. Detrital consumers in natural systems. In: The stream ecosystem. Technical Report 7. East Lansing, MI: Michigan State University, Institute of Water Research; 1969: 20-23.

Vannote, R. L.; Minshall, G. W.; Cummins, K. W.; Sedell, J. R.; Cushing, C. E. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 37: 130-137; 1980.

Wellner, C. A. Estimating light intensity beneath coniferous forest canopies: simple field method. Research Note INT-250. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 3 p.

Welsh, S. L.; Altwood, N. D.; Goodrich, S.; Neese, E.; Thorne, K. H.; Albe, B. Preliminary index of Utah vascular plant names. Great Basin Naturalist. 41(1): 1-108; 1981.

Welty, L. E.; Anderson, R. L.; Delaney, R. H.; Hensleigh, P. F. Glyphosate timing effects on establishment of sod-seeded legumes and grasses. Agronomy Journal. 73: 813-817; 1981.

Wendler, H. O.; Deschamps, G. Logging dams on coastal Washington streams. Washington Department of Fisheries Research Paper. 1(3): 27-38; 1955.

The West Shore. 9:128. Portland, OR; 1883.

Whitson, T. D.; William, R. D.; Parker, R.; Swan, D. G.; Dewey, S. Pacific Northwest weed control handbook. Corvallis, OR; Pullman, WA: Extension Services of Oregon State University, Washington State University, and the University of Idaho; 1985. 213 p.

Wiggins, G. B.; MacKay, R. J. Some relationships between systematics and trophic ecology of nearctic aquatic insects, with special reference to Trichoptera. Ecology. 59: 1211-1220; 1978.

Williams, C. Bridge of the Gods, mountains of fire, a return to the Columbia Gorge. White Salmon, WA: Friends of the Earth, New York and Elephant Mountain Arts; 1980. 191 p.

Williams, I. A. Drainage of farm lands in the Willamette and tributary valleys of Oregon. In: The mineral resources of Oregon. Salem, OR: Oregon Bureau of Mines and Geology. 1(4): 140-180; 1914.

APPENDIX 1: STATISTICAL TABLES

Table 30—Cumulative Normal Frequency Distribution area under the standard normal curve from 0 to Z

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
.9	.3159	.3286	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
3.2	.4993	.4993	.4994	.4994	.4994	.4994	.4994	.4995	.4995	.4995
3.3	.4995	.4995	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4997
3.4	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4998
3.6	.4998	.4998	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.9	.5000									

APPENDIX 1 (Con.)

Table 31—Ordinates of the normal curve

	Second decimal place in Z									
Z	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0.0	0.3989	0.3989	0.3989	0.3988	0.3986	0.3984	0.3982	0.3980	0.3977	0.3973
.1	.3970	.3965	.3961	.3956	.3951	.3945	.3939	.3932	.3925	.3918
.2	.3910	.3902	.3894	.3885	.3876	.3867	.3857	.3847	.3836	.3825
.3	.3814	.3802	.3790	.3778	.3765	.3752	.3739	.3725	.3712	.3697
.4	.3683	.3668	.3653	.3637	.3621	.3605	.3589	.3572	.3555	.3538
.5	.3521	.3503	.3485	.3467	.3448	.3429	.3410	.3391	.3372	.3352
.6	.3332	.3312	.3292	.3271	.3251	.3230	.3209	.3187	.3166	.3144
.7	.3123	.3101	.3079	.3056	.3034	.3011	.2989	.2966	.2943	.2920
.8	.2897	.2874	.2850	.2827	.2803	.2780	.2756	.2732	.2709	.2685
.9	.2661	.2637	.2613	.2589	.2565	.2541	.2516	.2492	.2468	.2444
1.0	.2420	.2396	.2371	.2347	.2323	.2299	.2275	.2251	.2227	.2203
1.1	.2179	.2155	.2131	.2107	.2083	.2059	.2036	.2012	.1989	.1965
1.2	.1942	.1919	.1895	.1872	.1849	.1826	.1804	.1781	.1758	.1736
1.3	.1714	.1691	.1669	.1647	.1626	.1604	.1582	.1561	.1539	.1518
1.4	.1497	.1476	.1456	.1435	.1415	.1394	.1374	.1354	.1334	.1315
1.5	.1295	.1276	.1257	.1238	.1219	.1200	.1182	.1163	.1145	.1127
1.6	.1109	.1092	.1074	.1057	.1040	.1023	.1006	.0989	.0973	.0957
1.7	.0940	.0925	.0909	.0893	.0878	.0863	.0848	.0833	.0818	.0804
1.8	.0790	.0775	.0761	.0748	.0734	.0721	.0707	.0694	.0681	.0669
1.9	.0656	.0644	.0632	.0620	.0608	.0596	.0584	.0573	.0562	.0551
2.0	.0540	.0529	.0519	.0508	.0498	.0488	.0478	.0468	.0459	.0449
2.1	.0440	.0431	.0422	.0413	.0404	.0396	.0387	.0379	.0371	.0363
2.2	.0355	.0347	.0339	.0332	.0325	.0317	.0310	.0303	.0297	.0290
2.3	.0283	.0277	.0270	.0264	.0258	.0252	.0246	.0241	.0235	.0229
2.4	.0224	.0219	.0213	.0208	.0203	.0198	.0194	.0189	.0184	.0180
2.5	.0175	.0171	.0167	.0163	.0158	.0154	.0151	.0147	.0143	.0139
2.6	.0136	.0132	.0129	.0126	.0122	.0119	.0116	.0113	.0110	.0107
2.7	.0104	.0101	.0099	.0096	.0093	.0091	.0088	.0086	.0084	.0081
2.8	.0079	.0077	.0075	.0073	.0071	.0069	.0067	.0065	.0063	.0061
2.9	.0060	.0058	.0056	.0055	.0053	.0051	.0050	.0048	.0047	.0046

	First decimal place in Z									
	0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
3	0.0044	0.0033	0.0024	0.0017	0.0012	0.0009	0.0006	0.0004	0.0003	0.0002
4	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000

APPENDIX 2: ACCURACY, PRECISION, AND CONFIDENCE INTERVALS OF SELECTED VARIABLES

Table 32—Accuracy, precision, and confidence intervals for stream shore water depth

Stream	Mean depth	Confidence interval	Precision	Accuracy
	Feet	± *Percent*		
Horton Creek	0.2	19.8	Fair	Good
Gance Creek	.3	26.6	Poor	Fair
Frenchman Creek	.5	13.2	Fair	Fair
Johnson Creek	.3	16.5	Fair	Fair
South Fork Salmon River	.5	10.6	Good	Poor
Elk Creek	.3	12.9	Fair	Good

Table 33—Accuracy, precision, and confidence intervals for sun angle (arc)

Stream	Sun arc angle	Confidence interval	Precision	Accuracy
	Degrees	± *Percent*		
Horton Creek	—	—	—	—
Gance Creek	—	—	—	—
Frenchman Creek	122	1.5	Excellent	Good
Johnson Creek	148	.4	Excellent	Poor
South Fork Salmon River	109	4.0	Excellent	Excellent
Elk Creek	163	.6	Excellent	Poor

Table 34—Accuracy, precision, and confidence intervals for streambank soil alteration

Stream		Streambank alteration	Confidence interval	Precision	Accuracy
		Percent	± *Percent*		
Horton Creek	Natural	8	12	Fair	Good
	Artificial	22	8	Good	Good
Gance Creek	Natural	31	6	Good	Fair
	Artificial	13	13	Fair	Poor
Frenchman Creek	Natural	20	11	Fair	Fair
	Artificial	5	24	Poor	Poor
Johnson Creek	Natural	15	10	Fair	Fair
	Artificial	12	13	Fair	Poor
South Fork Salmon River	Natural	21	12	Fair	Poor
	Artificial	7	15	Fair	—
Elk Creek	Natural	25	7	Good	Good
	Artificial	14	10	Fair	Poor

Table 35—Accuracy, precision, and confidence intervals for streambank vegetative stability

Stream	Streambank vegetative stability	Confidence interval	Precision	Accuracy
	Units	± *Percent*		
Horton Creek	3.3	2.2	Excellent	Fair
Gance Creek	1.8	5.7	Good	Fair
Frenchman Creek	3.3	2.5	Excellent	Good
Johnson Creek	3.3	2.4	Excellent	Good
South Fork Salmon River	3.5	2.3	Excellent	Fair
Elk Creek	2.8	3.5	Excellent	Fair

Table 36—Accuracy, precision, and confidence intervals for streambank undercut

Stream	Streambank undercut	Confidence interval	Precision	Accuracy
	Degrees	± *Percent*		
Horton Creek	0.1	20.8	Poor	Good
Gance Creek	.1	30.5	Poor	Fair
Frenchman Creek	.5	15.2	Fair	Poor
Johnson Creek	.3	16.1	Fair	Poor
South Fork Salmon River	.4	14.2	Fair	Good
Elk Creek	.5	13.9	Fair	Good

Table 37—Accuracy, precision, and confidence intervals for streambank angle

Stream	Channel bank angle	Confidence interval	Precision	Accuracy
	Degrees	± *Percent*		
Horton Creek	107	3.9	Excellent	Good
Gance Creek	118	3.7	Excellent	Good
Frenchman Creek	97	4.2	Excellent	Good
Johnson Creek	97	4.8	Excellent	Poor
South Fork Salmon River	103	6.6	Good	Good
Elk Creek	103	3.2	Excellent	Good

Table 38—Accuracy, precision, and confidence intervals for streamside cover

Stream	Streamside cover	Confidence interval	Precision	Accuracy
	Units	± *Percent*		
Horton Creek	2.3	3.2	Excellent	Good
Gance Creek	2.2	5.8	Good	Poor
Frenchman Creek	2.1	3.5	Excellent	Poor
Johnson Creek	2.4	3.4	Excellent	Poor
South Fork Salmon River	2.3	4.1	Excellent	Poor
Elk Creek	2.0	4.4	Excellent	Poor

Table 39—Accuracy, precision, and confidence intervals for vegetation use (ocular)

Stream	Vegetation use	Confidence interval	Precision	Accuracy
	Percent	± *Percent*		
Horton Creek	29	5.8	Good	Excellent
Gance Creek	44	8.5	Good	Good
Frenchman Creek	11	32.5	Poor	Good
Johnson Creek	25	9.2	Good	Good
South Fork Salmon River	8	1.5	Excellent	Good
Elk Creek	31	14.7	Fair	Good

Table 40—Accuracy, precision, and confidence intervals for vegetation overhang

Stream	Vegetation overhang	Confidence interval	Precision	Accuracy
	Feet	± *Percent*		
Horton Creek	0.5	8.3	Good	Poor
Gance Creek	.1	33.1	Poor	Poor
Frenchman Creek	.6	14.0	Fair	Good
Johnson Creek	.6	13.4	Fair	Poor
South Fork Salmon River	.8	13.5	Fair	Good
Elk Creek	.5	12.0	Fair	Good

Line No. | DATA | Stream

DATA | Location

DATA | Date | Station - | Xsect | Tension | T , M

DATA | Stake Right | Stake Left | Waterup . | Waterdown | Distance

DATA | Rt. Undercut . | Rt. Height , | Lt. Undercut , | Lt. Height | No. Rds

Line No.														
	DATA	C	,	W	,	Horizontal .		To Tape .		Waterdepth .		Velocity .
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.

↓ ↓ ↓

	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.
	DATA		,		,	.	,	.	,	.	,	.

APPENDIX 3 (Con.)

Form SCS-SOILS-232C.
Rev. 12-70

SOIL DESCRIPTION

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Soil type		File No.
Area	Date	Stop No.
Classification		
Location		
N. veg. (or crop)		Climate
Parent material		
Physiography		
Relief	Drainage	Salt or alkali
Elevation	Gr. water	Stoniness
Slope	Moisture	
Aspect	Root distrib.	% Clay*
Erosion	% Coarse fragments *	% Coarser than V.F.S. *
Permeability		
Additional notes		

* Control section average

APPENDIX 3 (Con.)

Hori-zon	Depth	Color		Texture	Structure	Consistence			Reaction	Boundary			
		Dry	Moist			Dry	Moist	Wet					

APPENDIX 4: COMPUTER PROGRAM FOR HERBAGE PHYTOMASS AND UTILIZATION MEASUREMENTS

```
1000  REM
1005  REM
1010  REM
1015  REM    PROGRAM NAME: HERB-2
1020  REM
1025  REM
1030  REM    PROGRAM PREPARED BY:
1035  REM
1040  REM
1045  REM             ELIZABETH C. KENNEDY KETCHESON
1050  REM             COMPUTER PROGRAMMER ANALYST
1055  REM
1060  REM                        AND
1065  REM
1070  REM             RODGER LOREN NELSON
1075  REM             BIOLOGICAL TECHNICIAN
1080  REM
1085  REM
1090  REM
1095  REM             USDA - FOREST SERVICE
1100  REM             INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
1105  REM             FORESTRY SCIENCES LABORATORY
1110  REM             BOISE, IDAHO
1115  REM
1120  REM
1125  REM
1130  REM    THIS IS A DOUBLE-SAMPLING PHYTOMASS AND VEGETATION USE
1135  REM    AND BASIC HABITAT ANALYSIS PROGRAM FOR USE WITH AN
1140  REM    ELECTRONIC CAPACITANCE METER ON UP TO 10 PASTURES.
1145  REM    PRIMARY METER READINGS AND SECONDARY METER READINGS
1150  REM    AND VEGETATION WEIGHTS CAN BE INPUT FROM THE KEYBOARD
1155  REM    OR MASS STORAGE, AND CAN BE ACCOMPANIED BY UP TO FIVE
1160  REM    ADDITIONAL VARIABLES FOR BASIC STATISTICAL ANALYSIS
1165  REM    WITHOUT SUBJECTION TO THE DOUBLE-SAMPLING ROUTINE.
1170  REM    THE DOUBLE-SAMPLING ROUTINE CALCULATES AND PLOTS LINEAR
1175  REM    AND LOG-LINEAR REGRESSIONS AND OUTPUTS ALL NECESSARY
1180  REM    COEFFICIENTS AND CONFIDENCE STATISTICS AT THE REQUEST-
1185  REM    ED PROBABILITY LEVELS, AND CALCULATES ESTIMATED PHYTO-
1190  REM    MASS FROM THE REGRESSION RESULTS.  ADDITIONAL VARIABLES
1195  REM    ARE STATISTICALLY EVALUATED TO PROVIDE MEANS, CONFID-
1200  REM    ENCE INTERVALS, ANALYSIS OF VARIANCE, AND SITE-SPECIFIC
1205  REM    COMPARISONS OF MEANS BETWEEN ALL PASTURES.
1210  REM
1215  REM
1220  REM
1225  REM
1230  OPTION BASE 1
1235  DEG
1240  REM
1245  REM
1250  REM
1255  REM
1260  REM    THIS SECTION DIMENSIONS THE ARRAYS THAT CONTAIN THE t
1265  REM    VALUES FOR 1 THROUGH 60, DEGREES OF FREEDOM FOR THE
1270  REM    PROBABILITY LEVELS OF 90%, 95%, AND 99%.  THE VALUES
1275  REM    ARE THEN READ FROM DATA STATEMENTS INTO THE ARRAYS.
1280  REM
1285  REM
1290  REM
1295  REM
```

(con.)

```
1300   DIM T90(60),T95(60),T99(60)
1305   MAT T90=ZER
1310   MAT T95=ZER
1315   MAT T99=ZER
1320   FOR I=1 TO 60
1325       READ T90(I)
1330   NEXT I
1335   DATA 6.314,2.920,2.353,2.132,2.015,1.943,1.895,1.860,1.833,1.812
1340   DATA 1.796,1.782,1.771,1.761,1.753,1.746,1.740,1.734,1.729,1.725
1345   DATA 1.721,1.717,1.714,1.711,1.708,1.706,1.703,1.701,1.699,1.697
1350   DATA 1.696,1.694,1.693,1.691,1.690,1.689,1.688,1.686,1.685,1.684
1355   DATA 1.683,1.682,1.682,1.681,1.680,1.679,1.678,1.678,1.677,1.676
1360   DATA 1.675,1.675,1.674,1.674,1.673,1.673,1.672,1.672,1.671,1.671
1365   FOR I=1 TO 60
1370       READ T95(I)
1375   NEXT I
1380   DATA 12.706,4.303,3.182,2.776,2.571,2.447,2.365,2.306,2.262,2.228
1385   DATA 2.201,2.179,2.160,2.145,2.131,2.120,2.110,2.101,2.093,2.086
1390   DATA 2.080,2.074,2.069,2.064,2.060,2.056,2.052,2.048,2.045,2.042
1395   DATA 2.040,2.037,2.035,2.032,2.030,2.028,2.026,2.025,2.023,2.021
1400   DATA 2.020,2.018,2.017,2.015,2.014,2.013,2.012,2.010,2.009,2.008
1405   DATA 2.007,2.006,2.006,2.005,2.004,2.003,2.002,2.002,2.001,2.000
1410   FOR I=1 TO 60
1415       READ T99(I)
1420   NEXT I
1425   DATA 63.657,9.925,5.841,4.604,4.032,3.707,3.499,3.355,3.250,3.169
1430   DATA 3.106,3.055,3.012,2.977,2.947,2.921,2.898,2.878,2.861,2.845
1435   DATA 2.831,2.819,2.807,2.797,2.787,2.779,2.771,2.763,2.756,2.750
1440   DATA 2.745,2.740,2.734,2.729,2.724,2.720,2.716,2.712,2.708,2.704
1445   DATA 2.701,2.698,2.696,2.693,2.690,2.688,2.685,2.683,2.680,2.678
1450   DATA 2.676,2.674,2.673,2.671,2.669,2.667,2.665,2.664,2.662,2.660
1455   REM
1460   REM
1465   REM
1470   REM
1475   REM     THIS SECTION DIMENSIONS THE STRING AND NUMERIC ARRAYS.
1480   REM
1485   REM
1490   REM
1495   REM
1500   DIM T$[80],Vn$(50)[10],Sn$(20)[10]
1505   DIM Studysite$[40],Site$(10)[20],Grazed$(10)[20]
1510   DIM D(25,500),Sc(20)
1515   DIM Observation(10,25),Sum(10,25),Sum_squares(10,25),Mean(10,25)
1520   DIM Squared_sum(10,25),Sum_of_squares(10,25),Mean_square(10,25)
1525   DIM St_error(10,25),St_deviation(10,25),Limit(10,25)
1530   DIM Mean_sq_sum(25),Mean_sq_between(25),Mean_sq_within(25),Sum_of_sums(25)
,Sum_sq_within(25)
1535   DIM Total_obs(25),Df_between(25),Df_within(25),Df_total(25),F_value(25)
1540   DIM Pool_mean_sq(10,10,25),Pool_st_error(10,10,25),Site_spec_t(10,10,25)
1545   DIM Ln_cross_plt_wt(10),Ln_eng_plt_wt(10),Ln_met_plt_wt(10)
1550   DIM Lin_var_yhat(10),Lin_err_yhat(10),Lin_lim_yhat(10)
1555   DIM Lin_lim_pct(10),Lin_eng_phytom(10),Lin_met_phytom(10)
1560   DIM Dif_lin_eng_phy(10,10),Dif_lin_met_phy(10,10),Dif_lin_phy_pct(10,10)
1565   DIM Mx_dif_leng_phy(10,10),Mx_dif_lnmt_phy(10,10),Mx_dif_leng_pct(10,10)
1570   DIM Mn_dif_leng_phy(10,10),Mn_dif_lnmt_phy(10,10),Mn_dif_leng_pct(10,10)
1575   DIM Log_observation(10,25),Log_sum(10,25),Log_sum_squares(10,25),Log_mean(
10,25)
1580   DIM Log_squared_sum(10,25),Log_sum_of_sqs(10,25),Log_mean_square(10,25)
1585   DIM Lg_cross_plt_wt(10),Lg_eng_plt_wt(10),Lg_met_plt_wt(10)
1590   DIM Lg_av_var_yhat(10),Log_lim_yhat(10)
1595   DIM Tr_log_err_yhat(10),Tr_log_var_yhat(10),Eng_tr_err_yhat(10)
1600   DIM Log_lim_pct(10),Log_eng_phytom(10),Log_met_phytom(10)
```

(con)

```
1605  DIM Dif_log_eng_phy(10,10),Dif_log_met_phy(10,10),Dif_log_phy_pct(10,10)
1610  DIM Mx_dif_long_phy(10,10),Mx_dif_lgmt_phy(10,10),Mx_dif_long_pct(10,10)
1615  DIM Mn_dif_long_phy(10,10),Mn_dif_lgmt_phy(10,10),Mn_dif_long_pct(10,10)
1620  DIM Trlowlimlgyhat(10),Truplimlgyhat(10)
1625  DIM Trenlwlimlgyhat(10),Trenuplimlgyhat(10)
1630  REM
1635  REM
1640  REM
1645  REM
1650  REM    THIS SECTION INITIALIZES EACH OF THE ELEMENTS IN THE
1655  REM    NUMERIC ARRAYS TO EQUAL ZERO.
1660  REM
1665  REM
1670  REM
1675  REM
1680  MAT D=ZER
1685  MAT Sc=ZER
1690  MAT Observation=ZER
1695  MAT Sum=ZER
1700  MAT Sum_squares=ZER
1705  MAT Mean=ZER
1710  MAT Squared_sum=ZER
1715  MAT Sum_of_squares=ZER
1720  MAT Mean_square=ZER
1725  MAT St_error=ZER
1730  MAT St_deviation=ZER
1735  MAT Limit=ZER
1740  MAT Mean_sq_sum=ZER
1745  MAT Mean_sq_between=ZER
1750  MAT Sum_sq_within=ZER
1755  MAT Mean_sq_within=ZER
1760  MAT Sum_of_sums=ZER
1765  MAT Total_obs=ZER
1770  MAT Df_between=ZER
1775  MAT Df_within=ZER
1780  MAT Df_total=ZER
1785  MAT F_value=ZER
1790  MAT Pool_mean_sq=ZER
1795  MAT Pool_st_error=ZER
1800  MAT Site_spec_t=ZER
1805  MAT Ln_cross_plt_wt=ZER
1810  MAT Ln_eng_plt_wt=ZER
1815  MAT Ln_met_plt_wt=ZER
1820  MAT Lin_var_yhat=ZER
1825  MAT Lin_err_yhat=ZER
1830  MAT Lin_lim_yhat=ZER
1835  MAT Lin_lim_pct=ZER
1840  MAT Lin_eng_phytom=ZER
1845  MAT Lin_met_phytom=ZER
1850  MAT Dif_lin_eng_phy=ZER
1855  MAT Dif_lin_met_phy=ZER
1860  MAT Dif_lin_phy_pct=ZER
1865  MAT Mx_dif_leng_phy=ZER
1870  MAT Mx_dif_lnmt_phy=ZER
1875  MAT Mx_dif_leng_pct=ZER
1880  MAT Mn_dif_leng_phy=ZER
1885  MAT Mn_dif_lnmt_phy=ZER
1890  MAT Mn_dif_leng_pct=ZER
1895  MAT Log_observation=ZER
1900  MAT Log_sum=ZER
1905  MAT Log_sum_squares=ZER
1910  MAT Log_mean=ZER
1915  MAT Log_squared_sum=ZER
```

(con.)

```
1920  MAT Log_sum_of_sqs=ZER
1925  MAT Log_mean_square=ZER
1930  MAT Lg_cross_plt_wt=ZER
1935  MAT Lg_eng_plt_wt=ZER
1940  MAT Lg_met_plt_wt=ZER
1945  MAT Lg_av_var_yhat=ZER
1950  MAT Log_lim_yhat=ZER
1955  MAT Tr_log_err_yhat=ZER
1960  MAT Tr_log_var_yhat=ZER
1965  MAT Eng_tr_err_yhat=ZER
1970  MAT Log_lim_pct=ZER
1975  MAT Log_eng_phytom=ZER
1980  MAT Log_met_phytom=ZER
1985  MAT Dif_log_eng_phy=ZER
1990  MAT Dif_log_met_phy=ZER
1995  MAT Dif_log_phy_pct=ZER
2000  MAT Mx_dif_long_phy=ZER
2005  MAT Mx_dif_lgmt_phy=ZER
2010  MAT Mx_dif_long_pct=ZER
2015  MAT Mn_dif_long_phy=ZER
2020  MAT Mn_dif_lgmt_phy=ZER
2025  MAT Mn_dif_long_pct=ZER
2030  MAT Trlowlimlgyhat=ZER
2035  MAT Truplimlgyhat=ZER
2040  MAT Trenlwlimlgyhat=ZER
2045  MAT Trenuplimlgyhat=ZER
2050  REM
2055  REM
2060  REM
2065  REM
2070  REM     THIS SECTION INITIALIZES EACH OF THE UNDIMENSIONED
2075  REM     VARIABLES TO EQUAL ZERO.
2080  REM
2085  REM
2090  REM
2095  REM
2100  LET Lin_sum_of_xy=Linear_n=Lin_df_total=Lin_df_resid=Lin_df_regress=0
2105  LET Lin_sum_cross=Lin_sum_sq_res=Lin_mean_sq_res=Lin_error_est=0
2110  LET Lin_furnival_i=Linear_b=Lin_error_b=Linear_a=Linear_r_sq=0
2115  LET Linear_r=Lin_covar=Lin_mean_sq_reg=Lin_f_value=0
2120  LET Log_sum_of_xy=Logarithmic_n=Log_df_total=Log_df_resid=Log_df_regress=0
2125  LET Log_sum_cross=Log_sum_sq_res=Log_mean_sq_res=Log_error_est=0
2130  LET Log_furnival_i=Logarithmic_b=Log_error_b=Logarithmic_a=Logrithmic_r_sq
=0
2135  LET Logarithmic_r=Log_covar=Log_mean_sq_reg=Log_f_value=0
2140  REM
2145  REM
2150  REM
2155  REM
2160  REM     THIS SECTION ALLOWS THE OPERATOR TO INPUT THE
2165  REM     NAME OF THE DATA FILE TO BE SUMMARIZED.
2170  REM
2175  REM
2180  REM
2185  REM
2190  PRINTER IS 16
2195  PRINT PAGE
2200  PRINT "
          "
2205  PRINT "      YOU WILL BE ASKED TO INPUT THE NAME OF THE DATA FILE THAT YOU
 WANT      "
2210  PRINT "      TO RUN THROUGH THIS PROGRAM, FOLLOWED BY A COLON (:), FOLLOWE
D BY       "
```

(con.)

```
2215  PRINT "      THE NUMBER  OF THE MASS STORAGE DEVICE WHERE THE FILE IS STOR
ED (i.e.   "
2220  PRINT "      T14, T15, OR F8).  PRESS THE CONT KEY AFTER YOU HAVE TYPED IN
 THE      "
2225  PRINT "      FILE NAME.
       "
2230  PRINT "
       "
2235  LINPUT "PLEASE ENTER THE FILE NAME AND THE MASS STORAGE DEVICE.",File$
2240  ASSIGN #1 TO File$
2245  READ #1,1;T$,No,Nv,Vn$(*),Ns,Sn$(*),Sc(*)
2250  REDIM D(Nv,No)
2255  READ #1,2
2260  READ #1;D(*)
2265  REM
2270  REM
2275  REM
2280  REM
2285  REM    THIS SECTION DETERMINES THE YEAR OF THE SURVEY AND THE
2290  REM    STUDY SITE FROM THE NAME OF THE DATA FILE.
2295  REM
2300  REM
2305  REM
2310  REM
2315  LET Year=VAL(File$[4,5])+1900
2320  LET Site=VAL(File$[1,3])
2325  IF Site=501 THEN Studysite$="LOWER RED RIVER"
2330  IF Site=601 THEN Studysite$="LOWER BIG CREEK, UTAH"
2335  IF Site=602 THEN Studysite$="UPPER BIG CREEK, UTAH"
2340  IF Site=611 THEN Studysite$="OTTER CREEK, UTAH"
2345  IF Site=701 THEN Studysite$="CHIMNEY CREEK, NEVADA"
2350  IF Site=711 THEN Studysite$="TABOR CREEK, NEVADA"
2355  IF Site=801 THEN Studysite$="UPPER FRENCHMAN CREEK"
2360  IF Site=802 THEN Studysite$="LOWER FRENCHMAN CREEK"
2365  IF Site=871 THEN Studysite$="ELK CREEK"
2370  IF Site=881 THEN Studysite$="UPPER BEAR VALLEY CREEK"
2375  IF Site=882 THEN Studysite$="LOWER BEAR VALLEY CREEK"
2380  IF Site=901 THEN Studysite$="HORTON/POLE CREEK"
2385  IF Site=951 THEN Studysite$="GANCE CREEK, NEVADA"
2390  IF Site=971 THEN Studysite$="JOHNSON CREEK"
2395  IF Site=991 THEN Studysite$="UPPER STOLLE"
2400  IF Site=992 THEN Studysite$="STOLLE GUARD"
2405  IF Site=993 THEN Studysite$="STOLLE COUGAR"
2410  IF Site=994 THEN Studysite$="LOWER STOLLE"
2415  REM
2420  REM
2425  REM
2430  REM
2435  REM    THIS SECTION DETERMINES WHICH OF THE SITES WERE SAMPLED
2440  REM    AND WHICH OF THOSE SITES WERE GRAZED AND UNGRAZED.
2445  REM
2450  REM
2455  REM
2460  REM
2465  FOR S=1 TO Ns-1
2470      IF Sn$(S)[5,5]="1" THEN Site$(S)="STUDY SITE 1"
2475      IF Sn$(S)[5,5]="2" THEN Site$(S)="STUDY SITE 2"
2480      IF Sn$(S)[5,5]="3" THEN Site$(S)="STUDY SITE 3"
2485      IF Sn$(S)[5,5]="4" THEN Site$(S)="STUDY SITE 4"
2490  NEXT S
2495  FOR S=1 TO Ns-1
2500      IF Sn$(S)[7,10]="UNGR" THEN Grazed$(S)="UNGRAZED"
2505      IF Sn$(S)[7,10]="GRCA" THEN Grazed$(S)="GRAZED-CATTLE"
```

(con.)

```
2510       IF Sn$(S)[7,10]="GRSH" THEN Grazed$(S)="GRAZED-SHEEP"
2515    NEXT S
2520    LET Site$(Ns)="CALIBRATION DATA"
2525    REM
2530    REM
2535    REM
2540    REM
2545    REM     THIS SECTION ALLOWS THE OPERATOR TO SELECT THE CONFIDENCE
2550    REM     LEVEL TO BE USED IN THE STATISTICAL ANALYSES.
2555    REM
2560    REM
2565    REM
2570    REM
2575    PRINTER IS 16
2580    PRINT PAGE
2585    PRINT "
           "
2590    PRINT "      YOU WILL BE ASKED TO INPUT THE CONFIDENCE LEVEL ( 90, 95, 99
) YOU      "
2595    PRINT "      WANT TO USE IN THE STATISTICAL ANALYSIS.  PRESS THE CONT KEY
AFTER      "
2600    PRINT "      YOU HAVE TYPED IN THE CONFIDENCE LEVEL.
           "
2605    PRINT "
           "
2610    INPUT "PLEASE ENTER THE CONFIDENCE LEVEL ( 90, 95, 99 ).",Level
2615    REM
2620    REM
2625    REM
2630    REM
2635    REM     THIS SECTION CALCULATES THE BASIC STATISTICS ( THE SUMS, THE
2640    REM     MEANS, THE SUM OF THE SQUARES, THE MEAN OF THE SQUARES ) FOR
2645    REM     EACH OF THE VARIABLES FOR THE PRIMARY DATA.
2650    REM
2655    REM
2660    REM
2665    REM
2670    FOR S=1 TO Ns-1
2675       FOR I=2 TO Nv
2680          FOR J=Sc(S) TO Sc(S+1)-1
2685             IF D(I,J)=-9999999.99999 THEN 2725
2690             LET Observation(S,I)=Observation(S,I)+1
2695             LET Sum(S,I)=Sum(S,I)+D(I,J)
2700             LET Sum_squares(S,I)=Sum_squares(S,I)+D(I,J)^2
2705             IF D(I,J)=0 THEN 2725
2710             LET Log_observation(S,I)=Log_observation(S,I)+1
2715             LET Log_sum(S,I)=Log_sum(S,I)+LOG(D(I,J))
2720             LET Log_sum_squares(S,I)=Log_sum_squares(S,I)+LOG(D(I,J))^2
2725          NEXT J
2730          IF Observation(S,I)<=1 THEN 2780
2735          LET Mean(S,I)=Sum(S,I)/Observation(S,I)
2740          LET Squared_sum(S,I)=Sum(S,I)^2
2745          LET Sum_of_squares(S,I)=Sum_squares(S,I)-Squared_sum(S,I)/Observat
ion(S,I)
2750          LET Mean_square(S,I)=Sum_of_squares(S,I)/(Observation(S,I)-1)
2755          LET St_error(S,I)=(Mean_square(S,I)/Observation(S,I))^.5
2760          LET St_deviation(S,I)=Mean_square(S,I)^.5
2765          IF Level=90 THEN LET Limit(S,I)=St_error(S,I)*T90(Observation(S,I)
-1)
2770          IF Level=95 THEN LET Limit(S,I)=St_error(S,I)*T95(Observation(S,I)
-1)
2775          IF Level=99 THEN LET Limit(S,I)=St_error(S,I)*T99(Observation(S,I)
-1)
```

(con.)

```
2780          IF Log_observation(S,I)<=1 THEN 2805
2785          LET Log_mean(S,I)=Log_sum(S,I)/Log_observation(S,I)
2790          LET Log_squared_sum(S,I)=Log_sum(S,I)^2
2795          LET Log_sum_of_sqs(S,I)=Log_sum_squares(S,I)-Log_squared_sum(S,I)/
Log_observation(S,I)
2800          LET Log_mean_square(S,I)=Log_sum_of_sqs(S,I)/(Log_observation(S,I)
-1)
2805      NEXT I
2810  NEXT S
2815  REM
2820  REM
2825  REM
2830  REM
2835  REM    THIS SECTION CALCULATES THE BASIC STATISTICS ( THE SUMS, THE
2840  REM    MEANS, THE SUM OF THE SQUARES, THE MEAN OF THE SQUARES ) FOR
2845  REM    EACH OF THE VARIABLES FOR THE SECONDARY DATA.
2850  REM
2855  REM
2860  REM
2865  REM
2870  FOR I=2 TO Nv
2875      FOR J=Sc(Ns) TO No
2880          IF D(I,J)=-9999999.99999 THEN 2900
2885          LET Observation(Ns,I)=Observation(Ns,I)+1
2890          LET Sum(Ns,I)=Sum(Ns,I)+D(I,J)
2895          LET Sum_squares(Ns,I)=Sum_squares(Ns,I)+D(I,J)^2
2900          IF (D(I,J)=0) OR (D(I,J)=-9999999.99999) THEN 2920
2905          LET Log_observation(Ns,I)=Log_observation(Ns,I)+1
2910          LET Log_sum(Ns,I)=Log_sum(Ns,I)+LOG(D(I,J))
2915          LET Log_sum_squares(Ns,I)=Log_sum_squares(Ns,I)+LOG(D(I,J))^2
2920      NEXT J
2925      IF Observation(Ns,I)<=1 THEN 2975
2930      LET Mean(Ns,I)=Sum(Ns,I)/Observation(Ns,I)
2935      LET Squared_sum(Ns,I)=Sum(Ns,I)^2
2940      LET Sum_of_squares(Ns,I)=Sum_squares(Ns,I)-Squared_sum(Ns,I)/Observati
on(Ns,I)
2945      LET Mean_square(Ns,I)=Sum_of_squares(Ns,I)/(Observation(Ns,I)-1)
2950      LET St_error(Ns,I)=(Mean_square(Ns,I)/Observation(Ns,I))^.5
2955      LET St_deviation(Ns,I)=Mean_square(Ns,I)^.5
2960      IF Level=90 THEN LET Limit(Ns,I)=St_error(Ns,I)*T90(Observation(Ns,I)-
1)
2965      IF Level=95 THEN LET Limit(Ns,I)=St_error(Ns,I)*T95(Observation(Ns,I)-
1)
2970      IF Level=99 THEN LET Limit(Ns,I)=St_error(Ns,I)*T99(Observation(Ns,I)-
1)
2975      IF Log_observation(Ns,I)<=1 THEN 3000
2980      LET Log_mean(Ns,I)=Log_sum(Ns,I)/Log_observation(Ns,I)
2985      LET Log_squared_sum(Ns,I)=Log_sum(Ns,I)^2
2990      LET Log_sum_of_sqs(Ns,I)=Log_sum_squares(Ns,I)-Log_squared_sum(Ns,I)/L
og_observation(Ns,I)
2995      LET Log_mean_square(Ns,I)=Log_sum_of_sqs(Ns,I)/(Log_observation(Ns,I)-
1)
3000  NEXT I
3005  REM
3010  REM
3015  REM
3020  REM
3025  REM    THIS SECTION DOES THE ANALYSIS OF VARIANCE BETWEEN SITES
3030  REM    FOR EACH OF THE VARIABLES.
3035  REM
3040  REM
3045  REM
3050  REM
```

(con.

```
3055  FOR I=2 TO Nv
3060      LET Df_between(I)=Ns-2
3065      FOR S=1 TO Ns-1
3070          LET Total_obs(I)=Total_obs(I)+Observation(S,I)
3075          IF Observation(Ns,I)=0 THEN 3085
3080          LET Mean_sq_sum(I)=Mean_sq_sum(I)+Squared_sum(S,I)/Observation(Ns,
I)
3085          LET Sum_sq_within(I)=Sum_sq_within(I)+Sum_squares(S,I)
3090          LET Sum_of_sums(I)=Sum_of_sums(I)+Sum(S,I)
3095      NEXT S
3100      IF Total_obs(I)<=2 THEN 3135
3105      LET Df_total(I)=Total_obs(I)-1
3110      LET Df_within(I)=Df_total(I)-Df_between(I)
3115      LET Sum_of_sums(I)=Sum_of_sums(I)^2/(Sc(Ns)-1)
3120      LET Mean_sq_between(I)=(Mean_sq_sum(I)-Sum_of_sums(I))/Df_between(I)
3125      LET Mean_sq_within(I)=Sum_sq_within(I)/Df_within(I)
3130      LET F_value(I)=Mean_sq_between(I)/Mean_sq_within(I)
3135  NEXT I
3140  REM
3145  REM
3150  REM
3155  REM
3160  REM    THIS SECTION DOES THE SITE SPECIFIC COMPARISONS ( THE
3165  REM    T-VALUES ) FOR EACH OF THE VARIABLES.
3170  REM
3175  REM
3180  REM
3185  REM
3190  FOR I=2 TO Nv
3195      FOR S=1 TO Ns-2
3200          FOR S1=S+1 TO Ns-1
3205              LET Pool_mean_sq(S,S1,I)=(Sum_of_squares(S,I)+Sum_of_squares(S
1,I))/(Observation(S,I)-1+(Observations(S1,I)-1))
3210              IF Observation(S,I)<>Observation(S1,I) THEN 3230
3215              IF Observation(S,I)=0 THEN 3245
3220              LET Pool_st_error(S,S1,I)=(2*Pool_mean_sq(S,S1,I)/Observation(
S,I))^.5
3225              GOTO 3240
3230              IF (Observation(S,I)=0) OR (Observation(S1,I)=0) THEN 3245
3235              LET Pool_st_error(S,S1,I)=(Pool_mean_sq(S,S1,I)*((Observation(
S,I)+Observation(S1,I))/(Observation(S,I)*Observation(S1,I))))^.5
3240              LET Site_spec_t(S,S1,I)=(Mean(S,I)-Mean(S1,I))/Pool_st_error(S
,S1,I)
3245          NEXT S1
3250      NEXT S
3255  NEXT I
3260  REM
3265  REM
3270  REM
3275  REM
3280  REM    THIS SECTION ALLOWS THE OPERATOR TO SELECT THE EXPLANATORY
3285  REM    VARIABLE (X) AND THE RESPONSE VARIABLE (Y).
3290  REM
3295  REM
3300  REM
3305  REM
3310  PRINTER IS 16
3315  PRINT PAGE
3320  PRINT "
       "
3325  PRINT "     YOU WILL BE ASKED TO INPUT THE NUMBER OF THE EXPLANATORY VARI
ABLE (X)    "
3330  PRINT "     AND THE RESPONSE VARIABLE (Y).  PRESS THE CONT KEY AFTER YOU
```

(con.)

```
HAVE EN-   "
3335  PRINT "     TERED THE NUMBERS OF THE VARIABLES.
        "
3340  PRINT "
        "
3345  INPUT "PLEASE ENTER THE NUMBER OF THE EXPLANATORY VARIABLE (X)",X
3350  INPUT "PLEASE ENTER THE NUMBER OF THE RESPONSE VARIABLE (Y)",Y
3355  REM
3360  REM
3365  REM
3370  REM
3375  REM    THIS SECTION CALCULATES THE STATISTICS ( SUM OF X*Y, SUM OF
3380  REM    THE CROSSPRODUCTS, SUM OF THE SQUARES FOR THE REGRESSION,
3385  REM    MEAN OF THE SQUARES FOR THE REGRESSION, AND THE STANDARD
3390  REM    ERROR OF ESTIMATE ) FOR THE LINEAR REGRESSION AND FOR THE
3395  REM    LOGARITHMIC REGRESSION FOR THE SELECTED VARIABLES.
3400  REM
3405  REM
3410  REM
3415  REM
3420  FOR J=Sc(Ns) TO No
3425      LET Lin_sum_of_xy=Lin_sum_of_xy+D(X,J)*D(Y,J)
3430      IF (D(X,J)=0) OR (D(Y,J)=0) THEN 3440
3435      LET Log_sum_of_xy=Log_sum_of_xy+LOG(D(X,J))*LOG(D(Y,J))
3440  NEXT J
3445  LET Linear_n=Observation(Ns,X)
3450  LET Lin_df_total=Linear_n-1
3455  LET Lin_df_resid=Lin_df_total-1
3460  LET Lin_df_regress=1
3465  LET Lin_sum_cross=Lin_sum_of_xy-Sum(Ns,X)*Sum(Ns,Y)/Linear_n
3470  LET Lin_sum_sq_res=Sum_of_squares(Ns,Y)-Lin_sum_cross^2/Sum_of_squares(Ns,
X)
3475  LET Lin_mean_sq_res=Lin_sum_sq_res/Lin_df_resid
3480  LET Lin_error_est=Lin_mean_sq_res^.5
3485  LET Lin_furnival_i=Lin_error_est
3490  LET Linear_b=Lin_sum_cross/Sum_of_squares(Ns,X)
3495  LET Lin_error_b=(Lin_mean_sq_res/Sum_of_squares(Ns,X))^.5
3500  LET Linear_a=Mean(Ns,Y)-Linear_b*Mean(Ns,X)
3505  LET Linear_r_sq=Lin_sum_cross^2/Sum_of_squares(Ns,X)/Sum_of_squares(Ns,Y)
3510  LET Linear_r=Linear_r_sq^.5
3515  LET Lin_covar=Lin_sum_cross/Lin_df_total
3520  LET Lin_mean_sq_reg=Lin_sum_cross^2/Sum_of_squares(Ns,X)/Lin_df_regress
3525  LET Lin_f_value=Lin_mean_sq_reg/Lin_mean_sq_res
3530  LET Logarithmic_n=Log_observation(Ns,X)
3535  LET Log_df_total=Logarithmic_n-1
3540  LET Log_df_resid=Log_df_total-1
3545  LET Log_df_regress=1
3550  LET Log_sum_cross=Log_sum_of_xy-Log_sum(Ns,X)*Log_sum(Ns,Y)/Logarithmic_n
3555  LET Log_sum_sq_res=Log_sum_of_sqs(Ns,Y)-Log_sum_cross^2/Log_sum_of_sqs(Ns,
X)
3560  LET Log_mean_sq_res=Log_sum_sq_res/Log_df_resid
3565  LET Log_error_est=Log_mean_sq_res^.5
3570  LET Log_furnival_i=Log_error_est*EXP(Log_mean(Ns,Y))
3575  LET Logarithmic_b=Log_sum_cross/Log_sum_of_sqs(Ns,X)
3580  LET Log_error_b=(Log_mean_sq_res/Log_sum_of_sqs(Ns,X))^.5
3585  LET Logarithmic_a=Log_mean(Ns,Y)-Logarithmic_b*Log_mean(Ns,X)
3590  LET Logrithmic_r_sq=Log_sum_cross^2/Log_sum_of_sqs(Ns,X)/Log_sum_of_sqs(Ns
,Y)
3595  LET Logarithmic_r=Logrithmic_r_sq^.5
3600  LET Log_covar=Log_sum_cross/Log_df_total
3605  LET Log_mean_sq_reg=Log_sum_cross^2/Log_sum_of_sqs(Ns,X)/Log_df_regress
3610  LET Log_f_value=Log_mean_sq_reg/Log_mean_sq_res
3615  REM
```

(con.)

```
3620  REM
3625  REM
3630  REM
3635  REM    THIS SECTION PRINTS OUT THE GENERAL DATA FOR THE STUDY SITE.
3640  REM
3645  REM
3650  REM
3655  REM
3660  PRINTER IS 0
3665  PRINT USING 3670
3670  IMAGE 80("*")
3675  PRINT USING "K,25X,K,26X,K";"*","STREAMSIDE HERBAGE ANALYSIS","*"
3680  PRINT USING "K,20X,K,20X,K";"*","DOUBLE SAMPLING WITH CAPACITANCE METER","
*"
3685  PRINT USING 3670
3690  PRINT LIN(2)
3695  PRINT USING "K,X,K";"STUDY AREA:",Studysite$
3700  PRINT USING "K,X,4D";"YEAR OF SURVEY:",Year
3705  PRINT
3710  PRINT USING "K,X,2D";"NO. SITES EVALUATED:",Ns-1
3715  FOR S=1 TO Ns-1
3720      PRINT USING "5X,K,2X,K";Site$(S),Grazed$(S)
3725  NEXT S
3730  PRINT
3735  PRINT USING "K,X,K";"STARTING TEMP:","_______________"
3740  PRINT USING "K,4X,K";"RESET TEMP:","_______________"
3745  PRINT USING "K,4X,K";"RESET TEMP:","_______________"
3750  PRINT USING "K,3X,K";"FINISH TEMP:","_______________"
3755  PRINT
3760  PRINT USING "K,X,K";"DATA COLLECTION DATE:","_______________"
3765  PRINT USING "K,4X,K";"DATA COLLECTED BY:","_______________"
3770  PRINT USING "K,4X,K";"DATA EVALUATED BY:","_______________"
3775  PRINT LIN(2)
3780  REM
3785  REM
3790  REM
3795  REM
3800  REM    THIS SECTION PRINTS OUT THE RAW DATA FOR THE SECONDARY DATA SET.
3805  REM
3810  REM
3815  REM
3820  REM
3825  PRINT USING 3830;"RAW DATA LISTING"
3830  IMAGE  31("-"),X,K,X,31("-")
3835  PRINT LIN(1)
3840  PRINT USING "32X,K";"SECONDARY SAMPLE"
3845  PRINT LIN(1)
3850  PRINT USING "10X,K,7X,K,8X,K,6X,K";"GREEN WEIGHT","COMPOSITION","COVERAGE"
,"DISTANCE TO STREAM"
3855  PRINT USING 3860
3860  IMAGE 7X,18("-"),2X,16("-"),2X,15("-"),2X,18("-")
3865  PRINT USING "K,5X,K,8X,K,5X,K,2X,K,2X,K,2X,K,6X,K,8X,K";"METER","GM","OZ",
"% SHRUB","% GRASS","% COVER","% EXP","FT","M"
3870  PRINT USING 3875
3875  IMAGE 5("-"),2X,8("-"),2X,8("-"),2X,7("-"),2X,7("-"),2X,7("-"),2X,6("-"),2
X,8("-"),2X,8("-")
3880  FOR J=Sc(Ns) TO No
3885      IF D(8,J)=-9999999.99999 THEN 3905
3890      PRINT USING 3895;D(2,J),D(7,J),.03527*D(7,J),D(3,J),D(4,J),D(6,J),D(5,
J),D(8,J),.3048*D(8,J)
3895      IMAGE 1X,3D,4X,4D.D,4X,3D.2D,5X,3D,6X,3D,6X,3D,5X,3D,5X,M3D.D,3X,M3D.2
D
3900      GOTO 3915
```

(con.)

```
3905      PRINT USING 3910;D(2,J),D(7,J),.03527*D(7,J),D(3,J),D(4,J),D(6,J),D(5,
J),"----","----"
3910      IMAGE 1X,3D,4X,4D.D,4X,3D.2D,5X,3D,6X,3D,6X,3D,5X,3D,7X,K,6X,K
3915  NEXT J
3920  PRINT
3925  PRINT USING "19X,K";"** NOTE:  '----' INDICATES MISSING DATA **"
3930  PRINT LIN(2)
3935  REM
3940  REM
3945  REM
3950  REM
3955  REM    THIS SECTION PRINTS OUT THE RAW DATA FOR THE PRIMARY DATA SET.
3960  REM
3965  REM
3970  REM
3975  REM
3980  PRINT USING "32X,K";"PRIMARY SAMPLES"
3985  PRINT LIN(1)
3990  FOR S=1 TO Ns-1
3995      IF Grazed$(S)="UNGRAZED" THEN PRINT USING "29X,K,2X,K";Site$(S),Grazed
$(S)
4000      IF Grazed$(S)="GRAZED-CATTLE" THEN PRINT USING "27X,K,2X,K";Site$(S),G
razed$(S)
4005      IF Grazed$(S)="GRAZED-SHEEP" THEN PRINT USING "27X,K,2X,K";Site$(S),Gr
azed$(S)
4010      IF Grazed$(S)="UNGRAZED" THEN PRINT USING 4025
4015      IF Grazed$(S)="GRAZED-CATTLE" THEN PRINT USING 4030
4020      IF Grazed$(S)="GRAZED-SHEEP" THEN PRINT USING 4035
4025      IMAGE 29X,22("-")
4030      IMAGE 27X,27("-")
4035      IMAGE 27X,26("-")
4040      PRINT
4045      PRINT USING "17X,K,12X,K,10X,K";"COMPOSITION","COVERAGE","DISTANCE TO
STREAM"
4050      PRINT USING 4055
4055      IMAGE 14X,18("-"),4X,17("-"),4X,20("-")
4060      PRINT USING "4X,K,5X,K,2X,K,4X,K,2X,K,7X,K,10X,K";"METER","%  SHRUB","
%  GRASS","%  COVER","%  EXPD","FT","M"
4065      PRINT USING 4070
4070      IMAGE 3X,7("-"),4X,8("-"),2X,8("-"),4X,8("-"),2X,7("-"),4X,9("-"),3X,8
("-")
4075      FOR J=Sc(S) TO Sc(S+1)-1
4080          IF D(8,J)=-9999999.99999 THEN 4100
4085          PRINT USING 4090;D(2,J),D(3,J),D(4,J),D(6,J),D(5,J),D(8,J),.3048*D
(8,J)
4090          IMAGE 5X,3D,9X,3D,7X,3D,8X,3D,7X,3D,7X,M3D.D,5X,M3D.2D
4095          GOTO 4110
4100          PRINT USING 4105;D(2,J),D(3,J),D(4,J),D(6,J),D(5,J),"----","----"
4105          IMAGE 5X,3D,9X,3D,7X,3D,8X,3D,7X,3D,9X,K,8X,K
4110      NEXT J
4115      PRINT
4120      PRINT USING "19X,K";"** NOTE:  '----' INDICATES MISSING DATA **"
4125      PRINT LIN(2)
4130  NEXT S
4135  REM
4140  REM
4145  REM
4150  REM
4155  REM    THIS SECTION PRINTS OUT THE BASIC STATISTICS AND THE ANALYSES
4160  REM    OF VARIANCE FOR THE PRIMARY AND SECONDARY DATA.
4165  REM
4170  REM
4175  REM
```

(con.)

```
4180   REM
4185   PRINT USING 3670
4190   PRINT USING "K,27X,K,28X,K";"*","BASIC DATA MANIPULATION","*"
4195   PRINT USING 3670
4200   PRINT LIN(2)
4205   PRINT USING 4210;"SUMMARY STATISTICS"
4210   IMAGE 30("-"),X,K,X,30("-")
4215   PRINT LIN(1)
4220   FOR I=2 TO Nv
4225       IF I=2 THEN PRINT USING "11X,K,26X,K";"METER READING","ANALYSIS OF VAR
IANCE"
4230       IF I=3 THEN PRINT USING "14X,K,29X,K";"% SHRUB","ANALYSIS OF VARIANCE"
4235       IF I=4 THEN PRINT USING "14X,K,29X,K";"% GRASS","ANALYSIS OF VARIANCE"
4240       IF I=5 THEN PRINT USING "13X,K,28X,K";"% EXPOSED","ANALYSIS OF VARIANC
E"
4245       IF I=6 THEN PRINT USING "14X,K,29X,K";"% COVER","ANALYSIS OF VARIANCE"
4250       IF I=7 THEN PRINT USING "12X,K,27X,K";"CLIP WEIGHT","ANALYSIS OF VARIA
NCE"
4255       IF I=8 THEN PRINT USING "9X,K,24X,K";"DISTANCE TO STREAM","ANALYSIS OF
 VARIANCE"
4260       PRINT USING 4265
4265       IMAGE 37("-"),3X,40("-")
4270       PRINT USING "33X,2D,K,4X,K,9X,K,3X,K,2X,K";Level,"%","SOURCE","DF","ME
AN SQUARE","F-VALUE"
4275       PRINT USING 4280;"SITE","MEAN","VAR","SE","LIMITS"
4280       IMAGE K,2X,K,5X,K,6X,K,5X,K,3X,13("-"),2X,3("-"),2X,11("-"),2X,7("-")
4285       IF Total_obs(I)>2 THEN PRINT USING 4295;"BETWEEN SITES",Df_between(I),
Mean_sq_between(I),F_value(I)
4290       IF Total_obs(I)<=2 THEN PRINT USING 4300;"BETWEEN SITES"
4295       IMAGE 4("-"),2X,5("-"),2X,7("-"),2X,7("-"),2X,6("-"),3X,K,2X,3D,2X,7D.
3D,2X,4D.2D
4300       IMAGE 4("-"),2X,5("-"),2X,7("-"),2X,7("-"),2X,6("-"),3X,K
4305       FOR S=1 TO Ns-1
4310           IF Total_obs(I)<=2 THEN 4355
4315           IF S=1 THEN PRINT USING 4320;S,Mean(S,I),Mean_square(S,I),St_error
(S,I),Limit(S,I),"WITHIN SITES",Df_within(I),Mean_sq_within(I)
4320           IMAGE 1X,2D,3X,3D.1D,2X,5D.1D,2X,3D.3D,2X,3D.2D,3X,K,3X,3D,2X,7D.3
D
4325           IF S=2 THEN PRINT USING 4330;S,Mean(S,I),Mean_square(S,I),St_error
(S,I),Limit(S,I),"TOTAL",Df_total(I)
4330           IMAGE 1X,2D,3X,3D.1D,2X,5D.1D,2X,3D.3D,2X,3D.2D,3X,K,10X,3D
4335           IF S>2 THEN PRINT USING 4340;S,Mean(S,I),Mean_square(S,I),St_error
(S,I),Limit(S,I)
4340           IMAGE 1X,2D,3X,3D.1D,2X,5D.1D,2X,3D.3D,2X,3D.2D
4345       NEXT S
4350       IF Total_obs(I)>2 THEN 4365
4355       PRINT USING "40X,K";"WITHIN SITES"
4360       PRINT USING "1X,K,4X,K";"NO SITE-SPECIFIC DATA THIS VARIABLE","TOTAL"
4365       PRINT USING 4370
4370       IMAGE 4("-"),2X,5("-"),2X,7("-"),2X,7("-"),2X,6("-")
4375       PRINT USING 4380;"CAL",Mean(Ns,I),Mean_square(Ns,I),St_error(Ns,I),Lim
it(Ns,I),"CALIBRATION ANOVA IN REGRESSION ANALYSIS"
4380       IMAGE K,3X,3D.1D,2X,5D.1D,2X,3D.3D,2X,3D.2D,3X,K
4385       PRINT LIN(1)
4390   NEXT I
4395   REM
4400   REM
4405   REM
4410   REM
4415   REM    THIS SECTION PRINTS OUT THE SITE SPECIFIC COMPARISONS FOR EACH
4420   REM    OF THE VARIABLES IN THE PRIMARY DATA SET.
4425   REM
4430   REM
```

(con.)

```
4435  REM
4440  REM
4445  PRINT LIN(2)
4450  PRINT USING 4455;"SITE SPECIFIC COMPARISONS (T-VALUES) BY VARIABLE"
4455  IMAGE 15("-"),X,K,X,15("-")
4460  PRINT LIN(1)
4465  FOR I=1 TO 2
4470      PRINT USING "46X,K";"VARIABLE"
4475      PRINT USING 4480
4480      IMAGE 25X,45("-")
4485      IF I=1 THEN PRINT USING "32X,K,17X,K";"METER","COMPOSITION"
4490      IF I=2 THEN PRINT USING "31X,K,17X,K";"COVERAGE","TO STREAM"
4495      PRINT USING 4500
4500      IMAGE 25X,20("-"),5X,20("-")
4505      PRINT USING 4510;"STUDY SITES","CALC-T","T(",Level,"%)","DF","CALC-T",
"T(",Level,"%)","DF"
4510      IMAGE 9X,K,5X,K,2X,K,2D,K,3X,K,6X,K,2X,K,2D,K,3X,K
4515      PRINT USING 4520
4520      IMAGE 9X,11("-"),5X,6("-"),2X,6("-"),2X,4("-"),5X,6("-"),2X,6("-"),2X,
4("-")
4525      FOR S=1 TO Ns-2
4530          FOR S1=S+1 TO Ns-1
4535              LET V1=V2=V3=V4=0
4540              IF I=2 THEN 4570
4545              LET V1=ABS(Site_spec_t(S,S1,2))
4550              LET V2=Observation(S,2)+Observation(S1,2)-2
4555              LET V3=ABS(Site_spec_t(S,S1,3))
4560              LET V4=Observation(S,3)+Observation(S1,3)-2
4565              GOTO 4590
4570              LET V1=ABS(Site_spec_t(S,S1,5))
4575              LET V2=Observation(S,5)+Observation(S1,5)-2
4580              LET V3=ABS(Site_spec_t(S,S1,8))
4585              LET V4=Observation(S,8)+Observation(S1,8)-2
4590              IF (V4>0) AND (Level=90) THEN PRINT USING 4620;S," vs",S1,V1,T
90(V2),V2,V3,T90(V4),V4
4595              IF (V4<=0) AND (Level=90) THEN PRINT USING 4625;S," vs",S1,V1,
T90(V2),V2
4600              IF (V4>0) AND (Level=95) THEN PRINT USING 4620;S," vs",S1,V1,T
95(V2),V2,V3,T95(V4),V4
4605              IF (V4<=0) AND (Level=95) THEN PRINT USING 4625;S," vs",S1,V1,
T95(V2),V2
4610              IF (V4>0) AND (Level=99) THEN PRINT USING 4620;S," vs",S1,V1,T
99(V2),V2,V3,T99(V4),V4
4615              IF (V4<=0) AND (Level=99) THEN PRINT USING 4625;S," vs",S1,V1,
T99(V2),V2
4620              IMAGE 11X,2D,K,2D,7X,2D.3D,2X,2D.3D,2X,4D,5X,2D.3D,2X,2D.3D,2X
,4D
4625              IMAGE 11X,2D,K,2D,7X,2D.3D,2X,2D.3D,2X,4D,6X,"----",4X,"----",
4X,"--"
4630          NEXT S1
4635      NEXT S
4640      PRINT LIN(1)
4645  NEXT I
4650  PRINT USING "19X,K";"** NOTE:  '----' INDICATES MISSING DATA **"
4655  PRINT LIN(2)
4660  REM
4665  REM
4670  REM
4675  REM
4680  REM    THIS SECTION PRINTS OUT THE SUMMARY STATISTICS AND THE ANALYSIS
4685  REM    OF VARIANCE FOR THE LINEAR REGRESSION MODEL.
4690  REM
4695  REM
```

(con.)

```
4700  REM
4705  REM
4710  PRINT USING 3670
4715  PRINT USING "K,25X,K,26X,K";"*","SECONDARY DATA MANIPULATION","*"
4720  PRINT USING "K,18X,K,18X,K";"*","LINEAR AND LOGARITHMIC REGRESSION ANALYSE
S","*"
4725  PRINT USING 3670
4730  PRINT LIN(2)
4735  PRINT USING 4740;"LINEAR REGRESSION MODEL: Y = A+BX"
4740  IMAGE 21("-"),X,K,X,24("-")
4745  PRINT LIN(1)
4750  PRINT USING 4755;"SUMMARY STATISTICS","ANALYSIS OF VARIANCE"
4755  IMAGE 8("-"),X,K,X,8("-"),8X,7("-"),X,K,X,7("-")
4760  PRINT LIN(1)
4765  PRINT USING "2X,K,7X,K,9X,K,9X,K,12X,K,4X,K,3X,K,3X,K";"N","B","Sb","A","S
OURCE","DF","MEAN SQUARE","F-VALUE"
4770  PRINT USING 4775
4775  IMAGE X,3("-"),3X,7("-"),3X,8("-"),3X,8("-"),8X,8("-"),2X,3("-"),2X,12("-"
),2X,7("-")
4780  PRINT USING 4785;Linear_n,Linear_b,Lin_error_b,Linear_a,"REGRESS.",Lin_df_
regress,Lin_mean_sq_reg,Lin_f_value
4785  IMAGE X,3D,3X,2D.4D,3X,3D.4D,3X,3D.4D,8X,K,2X,3D,2X,7D.4D,2X,4D.2D
4790  PRINT USING "44X,K,2X,3D,2X,7D.4D";"RESIDUAL",Lin_df_resid,Lin_mean_sq_res
4795  PRINT USING "2X,K,7X,K,7X,K,6X,K,10X,K,5X,3D";"R","RSQ","Syx","COVAR","TOT
AL",Lin_df_total
4800  PRINT USING 4805
4805  IMAGE 6("-"),3X,6("-"),3X,7("-"),3X,8("-")
4810  PRINT USING "1D.4D,3X,1D.4D,3X,2D.4D,3X,5D.2D,8X,K,X,3D.4D";Linear_r,Linea
r_r_sq,Lin_error_est,Lin_covar,"FURNIVAL'S INDEX =",Lin_furnival_i
4815  PRINT LIN(3)
4820  REM
4825  REM
4830  REM
4835  REM
4840  REM    THIS SECTION PRINTS OUT THE SUMMARY STATISTICS AND THE ANALYSIS
4845  REM    OF VARIANCE FOR THE LOGARITHMIC REGRESSION MODEL.
4850  REM
4855  REM
4860  REM
4865  REM
4870  PRINT USING 4875;"LOGARITHMIC REGRESSION MODEL:  LNY = A+BLNX"
4875  IMAGE 17("-"),X,K,X,18("-")
4880  PRINT LIN(1)
4885  PRINT USING 4755;"SUMMARY STATISTICS","ANALYSIS OF VARIANCE"
4890  PRINT LIN(1)
4895  PRINT USING "2X,K,7X,K,9X,K,9X,K,12X,K,4X,K,3X,K,3X,K";"N","B","Sb","A","S
OURCE","DF","MEAN SQUARE","F-VALUE"
4900  PRINT USING 4775
4905  PRINT USING 4785;Logarithmic_n,Logarithmic_b,Log_error_b,Logarithmic_a,"RE
GRESS.",Log_df_regress,Log_mean_sq_reg,Log_f_value
4910  PRINT USING "44X,K,2X,3D,2X,7D.4D";"RESIDUAL",Log_df_resid,Log_mean_sq_res
4915  PRINT USING "2X,K,7X,K,7X,K,6X,K,10X,K,5X,3D";"R","RSQ","Syx","COVAR","TOT
AL",Log_df_total
4920  PRINT USING 4805
4925  PRINT USING "1D.4D,3X,1D.4D,3X,2D.4D,3X,5D.2D,8X,K,X,3D.4D";Logarithmic_r,
Logrithmic_r_sq,Log_error_est,Log_covar,"FURNIVAL'S INDEX =",Log_furnival_i
4930  PRINT
4935  PRINT USING 3670
4940  PRINT LIN(4)
4945  GOTO 5120
4950  REM
4955  REM
4960  REM
```

(con.)

```
4965   REM
4970   REM    THIS SECTION IS A SUBROUTINE THAT ALLOWS THE OPERATOR TO SET UP
4975   REM    THE 9872B GRAPHICS PLOTTER FOR PLOTTING THE SECONDARY DATA AND
4980   REM    REGRESSION LINES.
4985   REM
4990   REM
4995   REM
5000   REM
5005 P:       ! PLOTTER SUBROUTINE
5010          PRINTER IS 16
5015          PRINT PAGE,"
                         "
5020          PRINT "     IT IS NOW TIME TO SET UP THE PLOTTER.  PLEASE FOLLOW T
HESE STEPS:        "
5025          PRINT "       1. PRESS THE CHART LOAD KEY ON THE PLOTTER.
                   "
5030          PRINT "       2. PUT THE PAPER ON THE PLOTTER WITH THE LOWER LEFT
 HAND CORNER       "
5035          PRINT "               OF THE PAPER SNUG IN THE LOWER LEFT HAND CO
RNER OF THE        "
5040          PRINT "               PLOTTER.  SMOOTH OUT ANY WRINKLES IN THE PA
PER.               "
5045          PRINT "       3. PRESS THE CHART HOLD KEY ON THE PLOTTER.
                   "
5050          PRINT "       4. PRESS THE P1 KEY ON THE PLOTTER.
                   "
5055          PRINT "       5. LOCATE THE PEN AT THE DESIRED LOWER LEFT HAND CO
RNER USING         "
5060          PRINT "               THE DIRECTIONAL ARROW KEYS, THE PEN DOWN KE
Y, AND THE         "
5065          PRINT "               PEN UP KEY.
                   "
5070          PRINT "       6. PRESS THE ENTER KEY ON THE PLOTTER.
                   "
5075          PRINT "       7. LOCATE THE PEN AT THE DESIRED UPPER RIGHT HAND C
ORNER USING        "
5080          PRINT "               THE DIRECTIONAL ARROW KEYS, THE PEN DOWN KE
Y, AND THE         "
5085          PRINT "               PEN UP KEY.
5090          PRINT "       8. PRESS THE ENTER KEY ON THE PLOTTER.
                   "
5095          PRINT "       9. WAIT NOW WHILE THE GRAPHS ARE PLOTTED.
                   "
5100          PRINT "
                   "
5105          PLOTTER IS 7,5,"9872A"
5110          LIMIT
5115          RETURN
5120   REM
5125   REM
5130   REM
5135   REM
5140   REM    THIS SECTION ALLOWS THE OPERATOR TO CHOOSE THE TYPE OF GRAPH
5145   REM    TO BE PLOTTED.
5150   REM
5155   REM
5160   REM
5165   REM
5170   PRINTER IS 16
5175   PRINT PAGE
5180   PRINT "
             "
```

(con.)

```
5185  PRINT "       YOU HAVE A CHOICE OF THE TYPE OF GRAPH YOU WOULD LIKE DRAWN
:         "
5190  PRINT "                1. AN ARITHMETIC PLOT
          "
5195  PRINT "                2. A LOGARITHMIC PLOT
          "
5200  PRINT "                3. NO PLOTS
          "
5205  PRINT "
          "
5210  INPUT "PLEASE ENTER THE NUMBER OF THE TYPE OF PLOT (1 OR 2 OR 3).",Plottyp
e
5215  IF (Plottype<1) OR (Plottype>3) THEN 5170
5220  IF Plottype=3 THEN 6270
5225  REM
5230  REM
5235  REM
5240  REM
5245  REM    THIS SECTION ALLOWS THE OPERATOR TO CHOOSE THE DEVICE ON WHICH
5250  REM    THE GRAPHS ARE TO BE PLOTTED ( THE CRT OR THE 9872B PLOTTER ).
5255  REM
5260  REM
5265  REM
5270  REM
5275  PRINT PAGE
5280  PRINT "
          "
5285  PRINT "      YOU WILL BE ASKED TO ENTER THE NUMBER OF THE DEVICE THAT YOU
WANT        "
5290  PRINT "      THE GRAPHS PLOTTED ON.  PLEASE ENTER A 1 IF YOU WANT THE GRAP
HS          "
5295  PRINT "      PLOTTED ON THE CRT OR A 2 IF YOU WANT THE GRAPHS PLOTTED ON T
HE          "
5300  PRINT "      9872B GRAPHICS PLOTTER.  PRESS THE CONT KEY AFTER YOU ENTER T
HE          "
5305  PRINT "      DEVICE NUMBER.
          "
5310  PRINT "
          "
5315  INPUT "PLEASE ENTER THE PLOTTER DEVICE NUMBER (1 OR 2).",Device
5320  IF Device=1 THEN 5380
5325  IF Device=2 THEN GOSUB P
5330  GOTO 5435
5335  REM
5340  REM
5345  REM
5350  REM
5355  REM    THIS SECTION SETS UP THE GRAPH.
5360  REM
5365  REM
5370  REM
5375  REM
5380  PLOTTER IS 13,"GRAPHICS"
5385  GRAPHICS
5390  REM
5395  REM
5400  REM
5405  REM
5410  REM    THIS SECTION DETERMINES THE X-SCALE.
5415  REM
5420  REM
5425  REM
5430  REM
```

(con.)

```
5435   LET Xmin=0
5440   LET Maximum_x=0
5445   FOR J=Sc(Ns) TO No
5450       IF D(X,J)<Maximum_x THEN 5460
5455       LET Maximum_x=D(X,J)
5460   NEXT J
5465   IF (Maximum_x>0) AND (Maximum_x<=25) THEN Xmax=25
5470   IF (Maximum_x>25) AND (Maximum_x<=50) THEN Xmax=50
5475   IF (Maximum_x>50) AND (Maximum_x<=100) THEN Xmax=100
5480   IF (Maximum_x>100) AND (Maximum_x<=250) THEN Xmax=250
5485   IF (Maximum_x>250) AND (Maximum_x<=500) THEN Xmax=500
5490   LET Xtic=Xmax/10
5495   REM
5500   REM
5505   REM
5510   REM
5515   REM    THIS SECTION DETERMINES THE Y-SCALE.
5520   REM
5525   REM
5530   REM
5535   REM
5540   LET Ymin=0
5545   LET Maximum_y=0
5550   FOR J=Sc(Ns) TO No
5555       IF D(Y,J)<Maximum_y THEN 5565
5560       LET Maximum_y=D(Y,J)
5565   NEXT J
5570   IF (Maximum_y>0) AND (Maximum_y<=25) THEN Ymax=25
5575   IF (Maximum_y>25) AND (Maximum_y<=50) THEN Ymax=50
5580   IF (Maximum_y>50) AND (Maximum_y<=100) THEN Ymax=100
5585   IF (Maximum_y>100) AND (Maximum_y<=250) THEN Ymax=250
5590   IF (Maximum_y>250) AND (Maximum_y<=500) THEN Ymax=500
5595   IF (Maximum_y>500) AND (Maximum_y<=1000) THEN Ymax=1000
5600   LET Ytic=Ymax/10
5605   IF Device=1 THEN SCALE -1.5*Xtic,10.5*Xtic,-1.5*Ytic,11.5*Ytic
5610   IF Device=2 THEN SCALE -1.5*Xtic,10.5*Xtic,-1.5*Ytic,11.5*Ytic
5615   CLIP Xmin,Xmax,Ymin,Ymax
5620   AXES 10*Xtic,10*Ytic,Xmin,Ymin
5625   UNCLIP
5630   REM
5635   REM
5640   REM
5645   REM
5650   REM    THIS SECTION DRAWS AND LABELS THE X AND Y AXES.
5655   REM
5660   REM
5665   REM
5670   REM
5675   PEN 1
5680   FOR Z=0 TO 10
5685       MOVE Z*Xtic,0
5690       DRAW Z*Xtic,-.1*Ytic
5695   NEXT Z
5700   FOR Z=0 TO 10
5705       MOVE 0,Z*Ytic
5710       DRAW -.1*Xtic,Z*Ytic
5715   NEXT Z
5720   IF Device=1 THEN CSIZE 2.5,.5
5725   IF Device=2 THEN CSIZE 2,.5
5730   LDIR 0
5735   LORG 4
5740   FOR Z=0 TO 10
5745       MOVE Z*Xtic,-.5*Ytic
```

(con.)

```
5750        IF Xmax=25 THEN LABEL USING "2D.D";Z*Xtic
5755        IF Xmax=50 THEN LABEL USING "2D";Z*Xtic
5760        IF (Xmax=100) OR (Xmax=250) OR (Xmax=500) THEN LABEL USING "3D";Z*Xtic
5765    NEXT Z
5770    LORG 2
5775    FOR Z=0 TO 10
5780        MOVE -.5*Xtic,Z*Ytic
5785        IF Ymax=25 THEN LABEL USING "2D.D";Z*Ytic
5790        IF Ymax=50 THEN LABEL USING "2D";Z*Ytic
5795        IF (Ymax=100) OR (Ymax=250) OR (Ymax=500) THEN LABEL USING "3D";Z*Ytic
5800        IF Ymax=1000 THEN LABEL USING "4D";Z*Ytic
5805    NEXT Z
5810    IF Device=1 THEN CSIZE 3,.5
5815    IF Device=2 THEN CSIZE 2.5,.5
5820    LORG 4
5825    MOVE .5*Xmax,-1.4*Ytic
5830    LABEL USING "K";"METER READING"
5835    LDIR 90
5840    LORG 6
5845    MOVE -1.4*Xtic,.5*Ymax
5850    LABEL USING "K";"GREEN (CLIP) WEIGHT (GM)"
5855    REM
5860    REM
5865    REM
5870    REM
5875    REM    THIS SECTION WRITES THE TITLE AND THE DESCRIPTIVE IN-
5880    REM    FORMATION FOR THE PLOT ON THE TOP OF THE PLOT.
5885    REM
5890    REM
5895    REM
5900    REM
5905    PEN 1
5910    IF Device=1 THEN CSIZE 3.5,.5
5915    IF Device=2 THEN CSIZE 3,.5
5920    LDIR 0
5925    LORG 6
5930    MOVE .5*Xmax,11*Ytic
5935    LABEL USING "K";T$
5940    IF Plottype=1 THEN LABEL USING "K,M2D.2D,K,2D.2D,K";"Yhat = ",Linear_a," +
 ",Linear_b,"*X"
5945    IF Plottype=2 THEN LABEL USING "K,M2D.2D,K,2D.2D,K";"LnYhat = ",Logarithmi
c_a," + ",Logarithmic_b,"*LnX"
5950    REM
5955    REM
5960    REM
5965    REM
5970    REM    THIS SECTION PLOTS THE POINTS.
5975    REM
5980    REM
5985    REM
5990    REM
5995    IF Device=1 THEN CSIZE 2.5,.5
6000    IF Device=2 THEN CSIZE 2,.5
6005    LORG 5
6010    FOR J=Sc(Ns) TO No
6015        MOVE D(X,J),D(Y,J)
6020        LABEL USING "K";"+"
6025    NEXT J
6030    PENUP
6035    REM
6040    REM
6045    REM
6050    REM
6055    REM    THIS SECTION PLOTS THE LINEAR REGRESSION LINE.
```

(con.)

```
6060  REM
6065  REM
6070  REM
6075  REM
6080  MOVE Xmin,Ymin
6085  IF Plottype=2 THEN 6130
6090  IF Xmax<=100 THEN Step=.1
6095  IF Xmax>100 THEN Step=1
6100  FOR J=0 TO Xmax STEP Step
6105      Yhat=Linear_a+Linear_b*J
6110      IF Yhat>Ymax THEN 6125
6115      DRAW J,Yhat
6120  NEXT J
6125  GOTO 6215
6130  REM
6135  REM
6140  REM
6145  REM
6150  REM     THIS SECTION PLOTS THE LOGARITHMIC REGRESSION LINE.
6155  REM
6160  REM
6165  REM
6170  REM
6175  IF Xmax<=100 THEN Step=.1
6180  IF Xmax>100 THEN Step=1
6185  FOR J=.0000000001 TO Xmax STEP Step
6190      LET Lg_var_yhat_plt=(Log_error_est*(1/Logarithmic_n+(LOG(J)-Log_mean(N
s,X))^2/Log_sum_of_sqs(Ns,X))^.5)^2
6195      LET Yhat=EXP(Logarithmic_a+Logarithmic_b*LOG(J)+Lg_var_yhat_plt/2)
6200      IF Yhat>Ymax THEN 6215
6205      DRAW J,Yhat
6210  NEXT J
6215  PEN 0
6220  IF Device=1 THEN DUMP GRAPHICS
6225  IF Device=1 THEN GCLEAR
6230  IF Device=1 THEN PRINTER IS 0
6235  IF Device=1 THEN PRINT LIN(4)
6240  PRINTER IS 16
6245  PRINT PAGE
6250  LINPUT "DO YOU WANT A DIFFERENT TYPE OF PLOT ? (Y OR N)",A$
6255  IF A$="Y" THEN 5170
6260  IF A$="N" THEN 6270
6265  GOTO 6245
6270  REM
6275  REM
6280  REM
6285  REM
6290  REM     THIS SECTION CALCULATES THE STANDING PHYTOMASS ESTIMATES
6295  REM     FOR ALL SITES IN BOTH ENGLISH AND METRIC UNITS FOR BOTH
6300  REM     THE LINEAR AND LOGARITHMIC REGRESSION MODELS.
6305  REM
6310  REM
6315  REM
6320  REM
6325  FOR S=1 TO Ns-1
6330      LET Ln_cross_plt_wt(S)=Linear_a+Linear_b*Mean(S,X)
6335      LET Ln_eng_plt_wt(S)=Ln_cross_plt_wt(S)*.03527
6340      LET Ln_met_plt_wt(S)=Ln_cross_plt_wt(S)/.929368
6345      LET Eng_ln_err_est=Lin_error_est*.03527
6350      LET Lin_var_yhat(S)=Eng_ln_err_est^2*(1/Linear_n+(Mean(S,X)-Mean(Ns,X)
)^2/Sum_of_squares(Ns,X))+(Mean_square(Ns,X)-Eng_ln_err_est^2)/Observation(S,X)
6355      LET Lin_err_yhat(S)=Lin_var_yhat(S)^.5
```

(con.)

```
6360      IF Level=90 THEN LET Lin_lim_yhat(S)=Lin_err_yhat(S)*T90(Observation(S
,X)-1)
6365      IF Level=95 THEN LET Lin_lim_yhat(S)=Lin_err_yhat(S)*T95(Observation(S
,X)-1)
6370      IF Level=99 THEN LET Lin_lim_yhat(S)=Lin_err_yhat(S)*T99(Observation(S
,X)-1)
6375      LET Lin_lim_pct(S)=(Mean(S,X)+Lin_lim_yhat(S)-(Mean(S,X)-Lin_lim_yhat(
S)))/Mean(S,X)*100
6380      LET Lin_eng_phytom(S)=Ln_cross_plt_wt(S)*48
6385      LET Lin_met_phytom(S)=Lin_eng_phytom(S)*1.1208
6390      LET A=Log_error_est^2*(1/Logarithmic_n+(Log_mean(S,X)-Log_mean(Ns,X))^
2/Log_sum_of_sqs(Ns,X))
6395      LET B=(Log_mean_square(Ns,X)-Log_error_est^2)/Log_observation(S,X)
6400      LET C=Logarithmic_a+Logarithmic_b*Log_mean(S,X)
6405      LET Lg_av_var_yhat(S)=A+B
6410      LET Log_av_err_yhat(S)=Lg_av_var_yhat(S)^.5
6415      LET Lg_cross_plt_wt(S)=EXP(Logarithmic_a+Logarithmic_b*Log_mean(S,X)+A
/2)
6420      LET Lg_eng_plt_wt(S)=Lg_cross_plt_wt(S)*.03527
6425      LET Lg_met_plt_wt(S)=Lg_cross_plt_wt(S)/.929368
6430      IF Level=90 THEN LET Log_lim_yhat(S)=Log_av_err_yhat(S)*T90(Log_observ
ation(S,X)-1)
6435      IF Level=95 THEN LET Log_lim_yhat(S)=Log_av_err_yhat(S)*T95(Log_observ
ation(S,X)-1)
6440      IF Level=99 THEN LET Log_lim_yhat(S)=Log_av_err_yhat(S)*T99(Log_observ
ation(S,X)-1)
6445      LET Lowlimlg_yhat(S)=Log_mean(S,X)-Log_lim_yhat(S)
6450      LET Uplimlg_yhat(S)=Log_mean(S,X)+Log_lim_yhat(S)
6455      LET Trlowlimlgyhat(S)=EXP(Lowlimlg_yhat(S)+Log_av_err_yhat(S)/2)
6460      LET Truplimlgyhat(S)=EXP(Uplimlg_yhat(S)+Log_av_err_yhat(S)/2)
6465      LET Log_lim_pct(S)=(Truplimlgyhat(S)-Trlowlimlgyhat(S))/Lg_cross_plt_w
t(S)*100
6470      LET Trenlwlimlgyhat(S)=Trlowlimlgyhat(S)*.03527
6475      LET Trenuplimlgyhat(S)=Truplimlgyhat(S)*.03527
6480      LET Log_eng_phytom(S)=Lg_cross_plt_wt(S)*48
6485      LET Log_met_phytom(S)=Log_eng_phytom(S)*1.1208
6490  NEXT S
6495  REM
6500  REM
6505  REM
6510  REM
6515  REM    THIS SECTION CALCULATES THE STANDING PHYTOMASS DIFFERENTIALS
6520  REM    FOR ALL SITES IN BOTH ENGLISH AND METRIC UNITS FOR BOTH THE
6525  REM    LINEAR AND LOGARITHMIC REGRESSION MODELS.
6530  REM
6535  REM
6540  REM
6545  REM
6550  FOR S=1 TO Ns-1
6555      FOR S1=1 TO Ns-1
6560          LET Dif_lin_eng_phy(S,S1)=Lin_eng_phytom(S)-Lin_eng_phytom(S1)
6565          LET Dif_lin_met_phy(S,S1)=Lin_met_phytom(S)-Lin_met_phytom(S1)
6570          LET Dif_lin_phy_pct(S,S1)=Dif_lin_eng_phy(S,S1)/Lin_eng_phytom(S)*
100
6575          LET Mx_dif_leng_phy(S,S1)=Lin_eng_phytom(S)+Lin_lim_yhat(S)*48-(Li
n_eng_phytom(S1)-Lin_lim_yhat(S1)*48)
6580          LET Mx_dif_lnmt_phy(S,S1)=Lin_met_phytom(S)+Lin_lim_yhat(S)*57.696
-(Lin_met_phytom(S1)-Lin_lim_yhat(S1)*57.696)
6585          LET Mx_dif_leng_pct(S,S1)=Mx_dif_leng_phy(S,S1)/(Lin_eng_phytom(S)
+Lin_lim_yhat(S))*100
6590          LET Mn_dif_leng_phy(S,S1)=Lin_eng_phytom(S)-Lin_lim_yhat(S)*48-(Li
n_eng_phytom(S1)+Lin_lim_yhat(S1)*48)
```

(con.)

```
6595          LET Mn_dif_lnmt_phy(S,S1)=Lin_met_phytom(S)-Lin_lim_yhat(S)*57.696
-(Lin_met_phytom(S1)+Lin_lim_yhat(S1)*57.696)
6600          LET Mn_dif_leng_pct(S,S1)=Mn_dif_leng_phy(S,S1)/(Lin_eng_phytom(S)
-Lin_lim_yhat(S))*100
6605          LET Dif_log_eng_phy(S,S1)=Log_eng_phytom(S)-Log_eng_phytom(S1)
6610          LET Dif_log_met_phy(S,S1)=Log_met_phytom(S)-Log_met_phytom(S1)
6615          LET Dif_log_phy_pct(S,S1)=Dif_log_eng_phy(S,S1)/Log_eng_phytom(S)*
100
6620          LET Mx_dif_long_phy(S,S1)=Log_eng_phytom(S)+Log_lim_yhat(S)*48-(Lo
g_eng_phytom(S1)-Log_lim_yhat(S1)*48)
6625          LET Mx_dif_lgmt_phy(S,S1)=Log_met_phytom(S)+Log_lim_yhat(S)*57.696
-(Log_met_phytom(S1)-Log_lim_yhat(S1)*57.696)
6630          LET Mx_dif_long_pct(S,S1)=Mx_dif_long_phy(S,S1)/(Log_eng_phytom(S)
+Log_lim_yhat(S))*100
6635          LET Mn_dif_long_phy(S,S1)=Log_eng_phytom(S)-Log_lim_yhat(S)*48-(Lo
g_eng_phytom(S1)+Log_lim_yhat(S1)*48)
6640          LET Mn_dif_lgmt_phy(S,S1)=Log_met_phytom(S)-Log_lim_yhat(S)*57.696
-(Log_met_phytom(S1)+Log_lim_yhat(S1)*57.696)
6645          LET Mn_dif_long_pct(S,S1)=Mn_dif_long_phy(S,S1)/(Log_eng_phytom(S)
-Log_lim_yhat(S))*100
6650      NEXT S1
6655  NEXT S
6660  REM
6665  REM
6670  REM
6675  REM
6680  REM    THIS SECTION PRINTS OUT THE STANDING PHYTOMASS ESTIMATES
6685  REM    AND DIFFERENTIALS BY SITE FOR THE LINEAR REGRESSION MODEL.
6690  REM
6695  REM
6700  REM
6705  REM
6710  PRINTER IS 0
6715  PRINT USING 3670
6720  PRINT USING "K,20X,K,21X,K";"*","STANDING HERBAGE PHYTOMASS ESTIMATION","*
"
6725  PRINT USING "K,24X,K,24X,K";"*","YIELD AND DIFFERENTIAL BY SITE","*"
6730  PRINT USING 3670
6735  PRINT LIN(2)
6740  PRINT USING 6745;"LINEAR REGRESSION MODEL"
6745  IMAGE 27("-"),X,K,X,28("-")
6750  PRINT LIN(1)
6755  PRINT USING "30X,K";"ESTIMATED PHYTOMASS"
6760  PRINT USING 6765
6765  IMAGE 30X,19("-")
6770  PRINT
6775  PRINT USING "14X,K,34X,K";"PER SAMPLE PLOT","TOTAL YIELD"
6780  PRINT USING 6785;Level,"%  CONF INT"
6785  IMAGE 10X,23("-"),5X,2D,K,5X,24("-")
6790  PRINT USING "1X,K,6X,K,4X,K,5X,K,7X,K,8X,K";"SITE","OZ/2FTSQ","GM/0.19MSQ"
,"(AS % OF EST)","LB/AC","KG/HA"
6795  PRINT USING 6800
6800  IMAGE 1X,4("-"),5X,10("-"),3X,10("-"),5X,13("-"),5X,10("-"),3X,10("-")
6805  FOR S=1 TO Ns-1
6810      PRINT USING 6815;S,Ln_eng_plt_wt(S),Ln_met_plt_wt(S),Lin_lim_pct(S),Li
n_eng_phytom(S),Lin_met_phytom(S)
6815      IMAGE 2X,2D,8X,3D.2D,7X,3D.2D,11X,3D.2D,9X,5D.2D,5X,5D.2D
6820  NEXT S
6825  PRINT LIN(2)
6830  PRINT USING "30X,K";"YIELD DIFFERENTIALS"
6835  PRINT USING 6765
6840  PRINT
6845  PRINT USING "21X,K,17X,K,16X,K";"MEAN","MAXIMUM","MINIMUM"
```

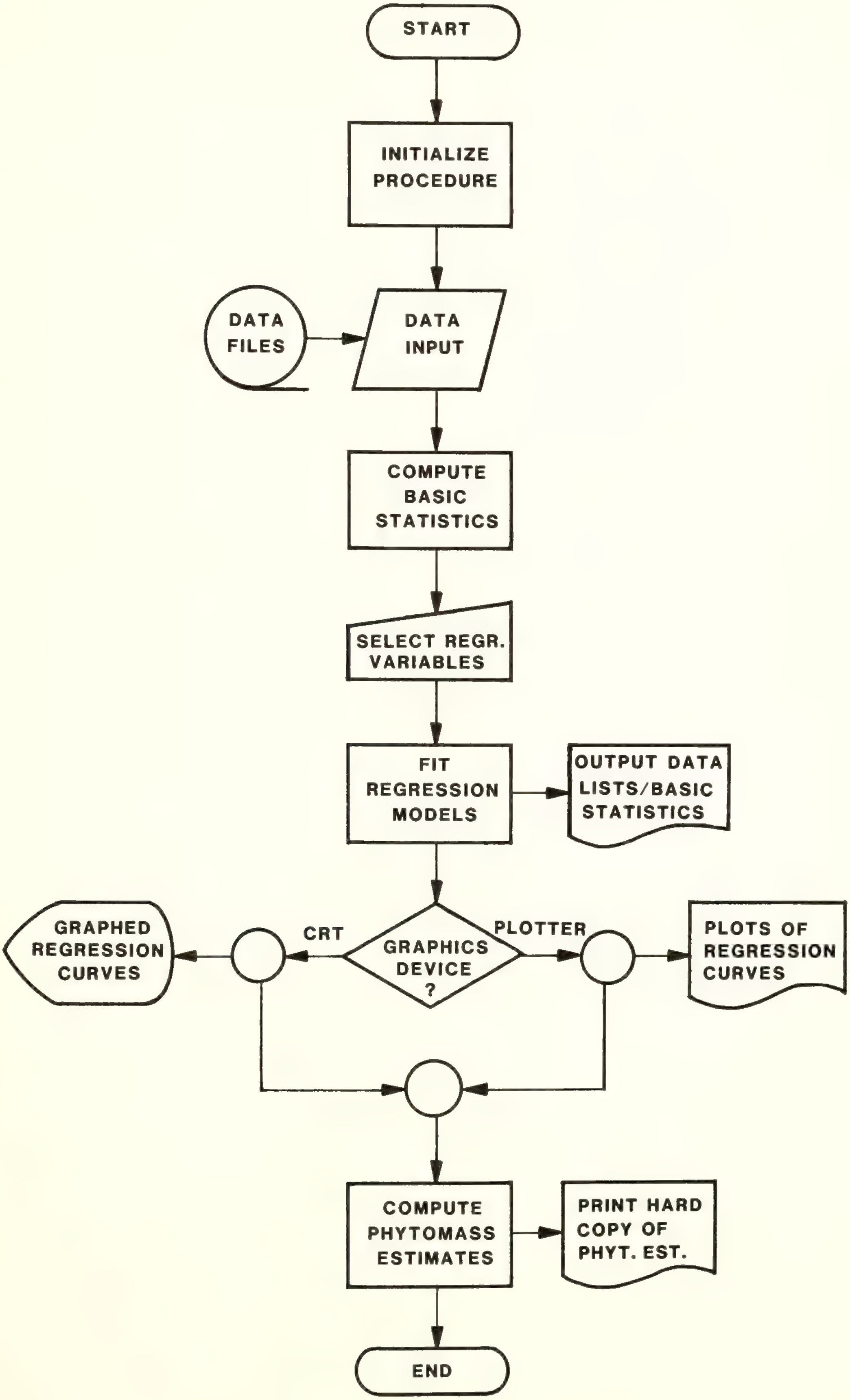
(con.)

```
6850   PRINT USING 6855
6855   IMAGE 12X,21("-"),2X,21("-"),2X,21("-")
6860   PRINT USING "2X,K,6X,K,4X,K,4X,K,4X,K,4X,K,4X,K,4X,K,4X,K,4X,K";"SITES","L
B/AC","KG/HA","%","LB/AC","KG/HA","%","LB/AC","KG/HA","%"
6865   PRINT USING 6870
6870   IMAGE 1X,7("-"),4X,7("-"),2X,7("-"),2X,3("-"),2X,7("-"),2X,7("-"),2X,3("-"
),2X,7("-"),2X,7("-"),2X,3("-")
6875   FOR S=1 TO Ns-1
6880       FOR S1=1 TO Ns-1
6885           LET D1=D2=D3=M1=M2=M3=M4=M5=M6=0
6890           IF S=S1 THEN 6955
6895           IF Dif_lin_eng_phy(S,S1)<0 THEN 6955
6900           LET D1=Dif_lin_eng_phy(S,S1)
6905           LET D2=Dif_lin_met_phy(S,S1)
6910           LET D3=Dif_lin_phy_pct(S,S1)
6915           LET M1=Mx_dif_leng_phy(S,S1)
6920           LET M2=Mx_dif_lnmt_phy(S,S1)
6925           LET M3=Mx_dif_leng_pct(S,S1)
6930           LET M4=Mn_dif_leng_phy(S,S1)
6935           LET M5=Mn_dif_lnmt_phy(S,S1)
6940           LET M6=Mn_dif_leng_pct(S,S1)
6945           PRINT USING 6950;S," -",S1,D1,D2,D3,M1,M2,M3,M4,M5,M6
6950           IMAGE 1X,2D,K,2D,5X,7D,2X,7D,2X,3D,2X,7D,2X,7D,2X,3D,2X,M6D,2X,M6D
,2X,3D
6955       NEXT S1
6960   NEXT S
6965   PRINT LIN(1)
6970   PRINT USING "15X,K";"NOTE:  A NEGATIVE SIGN INDICATES THAT THE SITE WITH"
6975   PRINT USING "15X,K";"       THE LESSER PHYTOMASS ESTIMATE HAS AN UPPER "
6980   PRINT USING "15X,K";"       LIMIT LARGER THAN THE ESTIMATED YIELD OF THE"
6985   PRINT USING "15X,K";"       SITE TO WHICH IT WAS COMPARED."
6990   PRINT LIN(2)
6995   REM
7000   REM
7005   REM
7010   REM
7015   REM    THIS SECTION PRINTS OUT THE STANDING PHYTOMASS ESTIMATES AND
7020   REM    DIFFERENTIALS BY SITE FOR THE LOGARITHMIC REGRESSION MODEL.
7025   REM
7030   REM
7035   REM
7040   REM
7045   PRINT USING 7050;"LOGARITHMIC REGRESSION MODEL"
7050   IMAGE 25("-"),X,K,X,25("-")
7055   PRINT LIN(1)
7060   PRINT USING "30X,K";"ESTIMATED PHYTOMASS"
7065   PRINT USING 6765
7070   PRINT
7075   PRINT USING "14X,K,34X,K";"PER SAMPLE PLOT","TOTAL YIELD"
7080   PRINT USING 6785;Level,"%  CONF INT"
7085   PRINT USING "1X,K,6X,K,4X,K,5X,K,7X,K,8X,K";"SITE","OZ/2FTSQ","GM/0.19MSQ"
,"(AS % OF EST)","LB/AC","KG/HA"
7090   PRINT USING 6800
7095   FOR S=1 TO Ns-1
7100       PRINT USING 6815;S,Lg_eng_plt_wt(S),Lg_met_plt_wt(S),Log_lim_pct(S),Lo
g_eng_phytom(S),Log_met_phytom(S)
7105   NEXT S
7110   PRINT LIN(2)
7115   PRINT USING "30X,K";"YIELD DIFFERENTIALS"
7120   PRINT USING 6765
7125   PRINT
7130   PRINT USING "21X,K,17X,K,16X,K";"MEAN","MAXIMUM","MINIMUM"
7135   PRINT USING 6855
```

(con.)

```
7140  PRINT USING "2X,K,6X,K,4X,K,4X,K,4X,K,4X,K,4X,K,4X,K,4X,K,4X,K";"SITES","L
B/AC","KG/HA","%","LB/AC","KG/HA","%","LB/AC","KG/HA","%"
7145  PRINT USING 6870
7150  FOR S=1 TO Ns-1
7155      FOR S1=1 TO Ns-1
7160          LET D1=D2=D3=M1=M2=M3=M4=M5=M6=0
7165          IF S=S1 THEN 7225
7170          IF Dif_log_eng_phy(S,S1)<0 THEN 7225
7175          LET D1=Dif_log_eng_phy(S,S1)
7180          LET D2=Dif_log_met_phy(S,S1)
7185          LET D3=Dif_log_phy_pct(S,S1)
7190          LET M1=Mx_dif_long_phy(S,S1)
7195          LET M2=Mx_dif_lgmt_phy(S,S1)
7200          LET M3=Mx_dif_long_pct(S,S1)
7205          LET M4=Mn_dif_long_phy(S,S1)
7210          LET M5=Mn_dif_lgmt_phy(S,S1)
7215          LET M6=Mn_dif_long_pct(S,S1)
7220          PRINT USING 6950;S," -",S1,D1,D2,D3,M1,M2,M3,M4,M5,M6
7225      NEXT S1
7230  NEXT S
7235  PRINT LIN(1)
7240  PRINT USING "15X,K";"NOTE:  A NEGATIVE SIGN INDICATES THAT THE SITE WITH"
7245  PRINT USING "15X,K";"       THE LESSER PHYTOMASS ESTIMATE HAS AN UPPER "
7250  PRINT USING "15X,K";"       LIMIT LARGER THAN THE ESTIMATED YIELD OF THE"
7255  PRINT USING "15X,K";"       SITE TO WHICH IT WAS COMPARED."
7260  PRINT LIN(2)
7265  PRINT USING 3670
7270  PRINT LIN(4)
7275  END
```

APPENDIX 5: FLOW CHART FOR HERB-2


START
INITIALIZE PROCEDURE
DATA FILES
DATA INPUT
COMPUTE BASIC STATISTICS
SELECT REGR. VARIABLES
FIT REGRESSION MODELS
OUTPUT DATA LISTS/BASIC STATISTICS
GRAPHED REGRESSION CURVES
CRT
GRAPHICS DEVICE ?
PLOTTER
PLOTS OF REGRESSION CURVES
COMPUTE PHYTOMASS ESTIMATES
PRINT HARD COPY OF PHYT. EST.
END

APPENDIX 6: REQUIREMENTS, EXAMPLE, AND COMPUTER PROGRAM FOR CALCULATING STREAM SURFACE SHADING FROM TOPOGRAPHIC AND VEGETATIVE FEATURES

Requirements:

1. HP-41C
2. Quad memory module
3. Printer
4. Card reader
5. Math Pac (only if using the entire temperature model) The source code is available on magnetic cards from:

   USDI-USF&WS-WELUT

   Instream Flow and Aquatic Systems Group

   Drake Creekside Bldg. 1

   2627 Redwing Road

   Fort Collins, CO 80526
6. The solar shade model requires 7 magnetic cards and is available at the above address.

HP-41C Shade Input/Output Example:

```
     XEQ "SHADE"

TRACE:Y/N?
N
                         RUN
ANGLES:D/R?
D                        RUN
TIME PER:M/D?
M                        RUN

LAT:D.M=?
                42.30    RUN
AR:D.M=?
                30.20    RUN
B:M=?
                10.0     RUN
aTE:D.M=?
                25.00    RUN
VCE:M=?
                  6.0    RUN
VHE:M=?
                  9.0    RUN
VOE:M=?
                  1.5    RUN
VDE:D=?
                  0.8    RUN
aTW:D.M=?
                25.00    RUN
VCW:M=?
                    0
                    0    RUN
VHW:M=?
VOW:M=?
                    0
                    0    RUN
VDW:D=?
                         RUN

MONTH:NO.=?
                5.009    RUN
INC:DAY=?
                    2    RUN
```

```
MONTH NO. 5
FROM: DAY=121
THRU: DAY=151

aS = 53.29 D.M.
ST = 0.0911 D
SW = 0.3034 D
Sh = 0.3945 D

MONTH NO. 6
FROM: DAY=152
THRU: DAY=181

aS= 55.37 D.M.
ST = 0.0838 D
SV = 0.2937 D
SH = 0.3774 D

MONTH NO. 7
FROM: DAY=182
THRU: DAY=212

aS = 54.38 D.M.
ST = 0.0872 D
SV = 0.2984 D
SH = 0.3856 D

MONTH NO. 8
FROM: DAY=213
THUR: DAY=243


aS = 50.11 D.M.
ST = 0.1019 D
SV = 0.3161 D
SH = 0.4180 D

MONTH NO. 9
FROM: DAY=244
THRU: DAY=273

aS = 42.36 D.M.
ST = 0.1281 D
SV = 0.3430 D
SH = 0.4711 D
```

HP-41C Source Code Listing for the Solar Shade Model: (Con.)

```
01♦LBL "SHADE"
02 CLRG
03 CF 29
04 RAD
05 FIX 0
06 "TRACE:Y/N?"
07 AVIEW
08 CF 02
09 AON
10 STOP
11 ASTO X
12 AOFF
13 "Y"
14 ASTO Y
15 X=Y?
16 SF 02
17 "ANGLES:D/R?"
18 AVIEW
19 CF 00
20 AON
21 STOP
22 ASTO X
23 AOFF
24 "R"
25 ASTO Y
26 X=Y?
27 SF 00
28 "TIME PER:M/D?"
29 AVIEW
30 SF 08
31 AON
32 STOP
33 ASTO X
34 AOFF
35 "D"
36 ASTO Y
37 X=Y?
38 CF 08
39 ADV
40 " :R=?"
41 ASTO 00
42 " :D.M=?"
43 ASTO 01
44 " :M=?"
45 ASTO 02
46 "LAT"
47 FS? 00
48 ARCL 00
49 FC? 00
50 ARCL 01
```

```
51 PROMPT
52 FS? 00
53 GTO 00
54 HR
55 D-R
56♦LBL 00
57 STO 12
58 SIN
59 STO 33
60 RCL 12
61 COS
62 STO 34
63 "AR"
64 FS? 00
65 ARCL 00
66 FC? 00
67 ARCL 01
68 PROMPT
69 FS? 00
70 GTO 00
71 HR
72 D-R
73♦LBL 00
74 STO 13
75 "B"
76 ARCL 02
77 PROMPT
78 STO 14
79 "aTE"
80 FS? 00
81 ARCL 00
82 FC? 00
83 ARCL 01
84 PROMPT
85 FS? 00
86 GTO 00
87 HR
88 D-R
89♦LBL 00
90 STO 15
91 TAN
92 STO 42
93 "VCE"
94 ARCL 02
95 PROMPT
96 STO 16
97 "VHE"
98 ARCL 02
99 PROMPT
100 STO 17
```

```
101 "VOE"
102 ARCL 02
103 PROMPT
104 STO 18
105 "VDE:D=?"
106 PROMPT
107 STO 19
108 "aTW"
109 FS? 00
110 ARCL 00
111 FC? 00
112 ARCL 01
113 PROMPT
114 FS? 00
115 GTO 00
116 HR
117 D-R
118♦LBL 00
119 STO 21
120 TAN
121 STO 43
122 "VCW"
123 ARCL 02
124 PROMPT
125 STO 22
126 "VHW"
127 ARCL 02
128 PROMPT
129 STO 23
130 "VOW"
131 ARCL 02
132 PROMPT
133 STO 24
134 "VDW:D=?"
135 PROMPT
136 STO 25
137♦LBL 99
138 ADV
139 ADV
140 FC? 08
141 GTO 00
142 1.031
143 STO 00
144 32.059
145 STO 01
146 60.090
147 STO 02
148 91.120
149 STO 03
150 121.151
```

(con.)

```
151 STO 04
152 152.181
153 STO 05
154 182.212
155 STO 06
156 213.243
157 STO 07
158 244.273
159 STO 08
160 274.304
161 STO 09
162 305.334
163 STO 10
164 335.365
165 STO 11
166 "MONTH:NO.=?"
167 PROMPT
168 STO 29
169 .011
170 STO 30
171 "INC:DAY=?"
172 PROMPT
173 1 E5
174 /
175♦LBL 01
176 ST+ IND 30
177 ISG 30
178 GTO 01
179 GTO 03
180♦LBL 00
181 12
182 "TIME PER.:NO.=?"
183 PROMPT
184 X>Y?
185 X<>Y
186 1 E3
187 /
188 1
189 +
190 STO 29
191 STO 30
192♦LBL 02
193 ADV
194 FIX 0
195 RCL 30
196 INT
197 "TIME PER. NO. "
198 ARCL X
199 AVIEW
200 "DAYS"
201 ARCL X
202 "⊢:JUL.=?"
203 1
204 -
205 PROMPT
206 STO IND Y
207 ISG 30
208 GTO 02
209♦LBL 03
210 ADV
211 ADV
212 FIX 0
213 0
214 STO 26
215 STO 27
216 STO 28
217 STO 56
218 RCL 29
219 INT
220 FS? 08
221 "MONTH NO. "
222 FC? 08
223 "TIME PER. NO. "
224 ARCL X
225 AVIEW
226 1
227 -
228 RCL IND X
229 STO 30
230♦LBL 04
231 SF 01
232 CF 09
233 1
234 ST+ 56
235 RCL 30
236 INT
237 FIX 0
238 "DAY= "
239 ARCL X
240 FC? 02
241 CF 21
242 ADV
243 AVIEW
244 SF 21
245 FIX 6
246 XEQ D
247 XEQ E
248 XEQ F
249 XEQ G
250 STO 55
251 CHS
252 STO 54
253 RCL 53
254 RCL 37
255 *
256 RCL 53
257 SIN
258 RCL 38
259 *
260 +
261 2
262 *
263 STO 40
264♦LBL 00
265 RCL 15
266 X≠0?
267 GTO 05
268 RCL 21
269 X=0?
270 GTO 06
271♦LBL 05
272 CF 03
273 RCL 39
274 RCL 13
275 ABS
276 X<=Y?
277 SF 03
278 FC? 03
279 XEQ A
280 FS? 03
281 XEQ B
282 FS? 09
283 GTO 14
284 XEQ C
285 CF 04
286 RCL 50
287 X<0?
288 SF 04
289 XEQ H
290 FS? 01
291 STO 54
292 FC? 01
293 STO 55
294 FS?C 01
295 GTO 05
296♦LBL 06
297 1
298 RCL 55
299 RCL 54
300 -
```

(con.)

```
301 RCL 37
302 *
303 RCL 55
304 SIN
305 RCL 54
306 SIN
307 -
308 RCL 38
309 *
310 +
311 RCL 40
312 /
313 -
314 ST+ 27
315 FC? 02
316 GTO 00
317 ADV
318 "ST= "
319 ARCL X
320 AVIEW
321♦LBL 00
322 SF 01
323 SF 04
324 SF 09
325 SF 10
326 .016
327 STO 31
328 0
329 STO 20
330 RCL 44
331 STO 46
332 RCL 55
333 RCL 54
334 -
335 16
336 /
337 STO 41
338 X=0?
339 GTO 08
340 0
341 STO 46
342♦LBL 07
343 FC?C 10
344 SF 10
345 16
346 RCL 31
347 INT
348 X=Y?
349 SF 09
350 RCL 41
351 *
352 RCL 54
353 +
354 STO 48
355 X>0?
356 CF 04
357 COS
358 RCL 38
359 *
360 RCL 37
361 +
362 ASIN
363 1 E-9
364 X<=Y?
365 X<>Y
366 STO 49
367 COS
368 STO 52
369 RCL 49
370 ST+ 46
371 FS? 10
372 ST+ 46
373 SIN
374 STO 51
375 RCL 33
376 *
377 RCL 35
378 -
379 RCL 34
380 /
381 RCL 52
382 /
383 ACOS
384 FS? 04
385 CHS
386 STO 50
387 RCL 13
388 X<=Y?
389 CF 01
390 -
391 SIN
392 ABS
393 RCL 52
394 *
395 RCL 51
396 /
397 FS? 01
398 RCL 17
399 FC? 01
400 RCL 23
401 *
402 FS? 01
403 RCL 16
404 FC? 01
405 RCL 22
406 2
407 /
408 FS? 01
409 RCL 18
410 FC? 01
411 RCL 24
412 -
413 +
414 RCL 14
415 X>Y?
416 X<>Y
417 0
418 X<=Y?
419 X<>Y
420 RCL 51
421 *
422 FS? 01
423 RCL 19
424 FC? 01
425 RCL 25
426 *
427 ST+ 20
428 FS? 10
429 ST+ 20
430 FC?C 09
431 GTO 00
432 2
433 /
434 ST- 20
435 RCL 49
436 2
437 /
438 ST- 46
439♦LBL 00
440 ISG 31
441 GTO 07
442 1.5
443 ST/ 41
444 RCL 20
445 RCL 41
446 *
447 RCL 14
448 RCL 40
449 *
450 /
```

(con.)

HP-41C Source Code Listing for the Solar Shade Model: (Con.)

```
451 ST+ 28
452 STO 47
453♦LBL 08
454 FC? 02
455 GTO 00
456 "SV= "
457 ARCL X
458 AVIEW
459♦LBL 00
460 RCL 44
461 RCL 46
462 X=Y?
463 GTO 00
464 RCL 41
465 *
466 RCL 55
467 RCL 54
468 -
469 /
470 STO 46
471 -
472 RCL 47
473 *
474 RCL 46
475 +
476♦LBL 00
477 ST+ 26
478 FC? 02
479 GTO 00
480 "aL= "
481 ARCL X
482 AVIEW
483 ADV
484♦LBL 00
485 ISG 30
486 GTO 04
487 RCL 56
488 ST/ 20
489 ST/ 26
490 ST/ 27
491 ST/ 28
492 RCL 29
493 1
494 -
495 RCL IND X
496 FIX 0
497 "FROM: DAY= "
498 ARCL X
499 AVIEW
500 STO Y
501 FRC
502 1000
503 *
504 X=0?
505 RCL Y
506 "THRU: DAY= "
507 ARCL X
508 AVIEW
509 ADV
510 FIX 2
511 RCL 26
512 R-D
513 HMS
514 "aS = "
515 ARCL X
516 "⊦ D.M"
517 AVIEW
518 FIX 4
519 RCL 27
520 "ST = "
521 ARCL X
522 "⊦ D"
523 AVIEW
524 RCL 28
525 "SV = "
526 ARCL X
527 "⊦ D"
528 AVIEW
529 +
530 "SH = "
531 ARCL X
532 "⊦ D"
533 AVIEW
534♦LBL 14
535 ISG 29
536 GTO 03
537 ADV
538 BEEP
539 GTO 99
540♦LBL D
541 172
542 X<>Y
543 -
544 PI
545 *
546 182.5
547 /
548 COS
549 .40928
550 *
551 STO 32
552 FC? 02
553 GTO 00
554 "DECL= "
555 ARCL X
556 AVIEW
557♦LBL 00
558 SIN
559 STO 35
560 RCL 33
561 *
562 STO 37
563 RCL 32
564 COS
565 STO 36
566 RCL 34
567 *
568 STO 38
569 RTN
570♦LBL E
571 RCL 37
572 RCL 38
573 +
574 ASIN
575 STO 44
576 FC? 02
577 RTN
578 "aSX= "
579 ARCL X
580 AVIEW
581 RTN
582♦LBL F
583 0
584 STO 50
585 CF 05
586 FS? 02
587 SF 05
588 FS? 05
589 CF 02
590 XEQ b
591 STO 45
592 FS? 05
593 SF 02
594 FC? 02
595 RTN
596 "aT0= "
597 ARCL X
598 AVIEW
599 RTN
600♦LBL G
```

(con.)

```
601 1
602 RCL 35
603 RCL 34
604 /
605 CHS
606 X>Y?
607 X<>Y
608 -1
609 X<=Y?
610 X<>Y
611 ACOS
612 STO 39
613 FC? 02
614 GTO 00
615 "AZ0= "
616 ARCL X
617 AVIEW
618♦LBL 00
619 RCL 37
620 RCL 38
621 /
622 CHS
623 ACOS
624 STO 53
625 FC? 02
626 RTN
627 "HRS0= "
628 ARCL X
629 AVIEW
630 RTN
631♦LBL A
632 RCL 44
633 RCL 45
634 X<=Y?
635 GTO 00
636 0
637 STO 46
638 STO 47
639 RTN
640♦LBL 00
641 FC? 01
642 GTO 00
643 RCL 39
644 CHS
645 STO 46
646 0
647 STO 47
648 RTN
649♦LBL 00
650 0
```

```
651 STO 46
652 RCL 39
653 STO 47
654 RTN
655♦LBL B
656 FC? 01
657 GTO 09
658 CF 09
659 RCL 44
660 RCL 45
661 X<=Y?
662 GTO 00
663 RCL 39
664 PI
665 RCL 13
666 X>0?
667 -
668 X<=0?
669 +
670 ABS
671 X>Y?
672 GTO 00
673 SF 09
674 "DOUBLE SUNSHINE"
675 "⊢ PERIOD"
676 AVIEW
677 "EXECUTION STOPP"
678 "⊢ED THIS"
679 AVIEW
680 "TIME PERIOD"
681 AVIEW
682 RTN
683♦LBL 00
684 RCL 39
685 CHS
686 STO 46
687 RCL 13
688 STO 47
689 X<=0?
690 RTN
691♦LBL 00
692 RCL 44
693 RCL 45
694 X>Y?
695 GTO 00
696 0
697 STO 47
698 RTN
699♦LBL 00
700 0
```

```
701 STO 46
702 RTN
703♦LBL 09
704 RCL 39
705 STO 47
706 RCL 13
707 STO 46
708 X>0?
709 RTN
710♦LBL 00
711 RCL 44
712 RCL 45
713 X>Y?
714 GTO 00
715 0
716 STO 46
717 RTN
718♦LBL 00
719 0
720 STO 47
721 RTN
722♦LBL C
723 FS? 02
724 ADV
725 RCL 46
726 RCL 47
727 +
728 2
729 /
730 STO 50
731 CF 07
732 FS? 02
733 SF 07
734 FS? 07
735 CF 02
736 XEQ b
737 STO 49
738 .020
739 STO 31
740♦LBL 10
741 XEQ a
742 XEQ b
743 CF 05
744 RCL 49
745 X>Y?
746 SF 05
747 RCL 50
748 FC? 01
749 GTO 11
750 FS? 05
```

(con.)

HP-41C Source Code Listing for the Solar Shade Model: (Con.)

```
751 STO 47
752 FC? 05
753 STO 46
754 GTO 12
755♦LBL 11
756 FS? 05
757 STO 46
758 FC? 05
759 STO 47
760♦LBL 12
761 RCL 46
762 RCL 47
763 +
764 2
765 /
766 STO 50
767 -
768 ABS
769 1 E-6
770 X>Y?
771 GTO 00
772 ISG 31
773 GTO 10
774♦LBL 00
775 XEQ b
776 STO 49
777 FS? 07
778 SF 02
779 FC? 02
780 RTN
781 FS? 01
782 "aLSR= "
783 FC? 01
784 "aLSS= "
785 ARCL 49
786 AVIEW
787 FS? 01
788 "AZSR= "
789 FC? 01
790 "AZSS= "
791 ARCL 50
792 AVIEW
793 RTN
794♦LBL a
795 RCL 50
796 COS
797 RCL 34
798 *
799 STO 41
800♦LBL 13
801 RCL 49
802 SIN
803 RCL 33
804 *
805 RCL 49
806 COS
807 RCL 41
808 *
809 -
810 RCL 35
811 -
812 STO 48
813 RCL 33
814 RCL 49
815 COS
816 *
817 RCL 41
818 RCL 49
819 SIN
820 *
821 +
822 /
823 ST- 49
824 ABS
825 1 E-6
826 X<=Y?
827 GTO 13
828 RCL 48
829 ABS
830 X>Y?
831 GTO 13
832 RCL 49
833 FC? 02
834 RTN
835 "aLS= "
836 ARCL X
837 AVIEW
838 RTN
839♦LBL b
840 RCL 50
841 RCL 13
842 CF 06
843 X<=Y?
844 SF 06
845 -
846 SIN
847 ABS
848 FC? 06
849 RCL 42
850 FS? 06
851 RCL 43
852 *
853 ATAN
854 FC? 02
855 RTN
856 "aLT= "
857 ARCL X
858 AVIEW
859 RTN
860♦LBL H
861 RCL 49
862 SIN
863 RCL 37
864 -
865 RCL 38
866 /
867 1
868 X>Y?
869 X<>Y
870 ACOS
871 FS? 04
872 CHS
873 FC? 02
874 RTN
875 FS? 01
876 "HRSR= "
877 FC? 01
878 "HRSS= "
879 ARCL X
880 AVIEW
881 RTN
882 END
```

APPENDIX 7: BIBLIOGRAPHIES, SOURCE MATERIALS, AND REPOSITORIES FOR INFORMATION ON HISTORICAL RIPARIAN CONDITIONS

Partial List of General Bibliographies and Indices

American Historical Association. Guide to historical literature. Rev. ed. Howe, G. F.; [and others], eds. New York: Macmillan; 1961. 997 p.

America: history and life. Santa Barbara, CA: ABC-Clio; 1964. 137 p.

Beers, H. P. Bibliographies in American history: guide to materials for research. Rev. ed. New York: Wilson; 1942. 502 p.

Cassara, E. History of the United States of America: a guide to information sources. Detroit: Gale Research; 1977. 459 p.

Catalogue of the public documents of the United States, 1893-1940. Washington, DC: U.S. Government Printing Office; 1896-1945. 25 vols.

Checklist of United States public documents, 1789-1909. 3d ed. Washington, DC: U.S. Government Printing Office; 1911. 1707 p.

Coulter, E. M.; Gerstenfeld, M. Historical bibliographies: a systematic and annotated guide. Berkeley, CA: University of California; 1935. 41 p.

Crouch, M.; Raum, H., compilers. Directory of state and local history periodicals. Chicago: American Library Association; 1977. 125 p.

Davis, R. C. North American forest history: a guide to archives and manuscripts in the United States and Canada. Forest History Society. Santa Barbara, CA: ABC-Clio; 1977. 376 p.

Directory of historical societies and agencies in the United States and Canada. McDonald, D., compiler and ed. 11th ed. Nashville, TN: American Association for State and Local History; 1978. 474 p.

Fahl, R. J. North American forest and conservation history: a bibliography. Forest History Society. Santa Barbara, CA: ABC-Clio; 1977. 408 p.

Faye, H. Picture sources: an introductory list. New York: Special Libraries Association; 1959. 115 p.

Gerould, W. G., ed. American newspapers, 1821-1936: a union list of files available in the United States and Canada. New York: H. W. Wilson; 1937. 807 p.

Guide to the American Historical Review, 1895-1945. Scott, F. D.; Teigler, E., compilers. Washington, DC: American Historical Association, 1945. 41 p.

Hamer, P. M. A guide to archives and manuscripts in the United States. New Haven, CT: Yale University Press for the National Historical Publications Committee; 1961. 775 p.

Harvard guide to American history. Rev. ed. Freidel, Frank, ed. Cambridge, MA: Belknap Press; 1974. 2 vols.

Historical abstracts, 1450 to present: bibliography of the world's periodical literature. Santa Barbara, CA: ABC-Clio; 1955. 652 p.

Nineteenth century readers' guide to periodical literature, 1890-1899. New York: H. W. Wilson; 1944. 2 vols plus supplement 1900-1922.

Numerical lists and schedule of volume. Washington, DC: U.S. Government Printing Office; 1942 to date.

Monthly catalog of United States government publications, 1895 to present. Washington, DC: U.S. Government Printing Office; 1895. Monthly.

Poole's index to periodical literature, 6 vols. Vol. 1, Boston: Osgood, 1882; vols 2-6, Boston: Houghton, 1888-1908.

Readers' guide to periodical literature. New York: H. W. Wilson; 1905.

Schmeckebier, L. F.; Eastin, R. B. Government publications and their use. 2d rev. ed. Washington, DC: The Brookings Institution; 1969. 510 p.

Sheehy, E. P. A guide to reference books. 9th ed. Chicago: American Library Association; 1976. 1033 p.

Shumway, G. L. Oral history in the United States: a directory. New York: Oral History Association; 1971. 120 p.

U.S. Bureau of the Budget. Statistical services of the United States government. Rev. ed. Washington, DC: U.S. Government Printing Office; 1968. 156 p.

U.S. Bureau of the Census. Historical statistics of the United States, colonial times to 1970. Bicentennial Edition. Washington, DC: U.S. Government Printing Office; 1975. 2 vols.

U.S. Library of Congress. The national union catalog of manuscript collections, 1959/61. Hamden, CT: Shoe String; 1962. 1253 p.

Vanderbilt, P. Guide to the special collections of prints and photographs in the Library of Congress. Washington, DC: U.S. Government Printing Office; 1955. 200 p.

Partial List of Pacific Northwest References

Drazon, Joseph G. The Pacific Northwest: an index to people and places in books. Metuchen, NJ: Scarecrow Press; 1979. 164 p.

Haskell, D. C. The United States exploring expedition 1838-1844 and its publications 1844-1874. Washington, DC: U.S. Government Printing Office; 1942. 188 p.

Hitt, J. M. A reference list of public documents, 1854-1918, found in the files of the (Washington) State Library. 1920. 41 p.

Judson, K. B. Subject index to the history of the Pacific Northwest and of Alaska as found in the United States government documents, congressional series, in the American State papers, and in other documents, 1789-1881. Olympia, WA: FM Lamborn, Public Printer; 1913. 341 p.

Moore, R. E.; Purcell, N. H., eds. Pacific Northwest Americana, 1949-1974: a supplement to Charles W. Smith's third edition 1950. 1st ed. Portland, OR: Binford and Mort; 1981. 365 p.

Oliphant, J. O. On the cattle ranges of the Oregon Country. Seattle, WA: University of Washington Press; 1968. 372 p.

Oregon Historical Records Survey. Guide to the manuscript collections of the Oregon Historical Society. Portland, OR; 1940. 133 p.

Oregon Historical Society. A bibliography of Pacific Northwest history. Portland, OR; 1958. 27 p.

Rockwood, E. R. Oregon state documents: a checklist, 1843-1925. Portland, OR: Oregon Historical Society; 1947. 283 p.

Smith, C. W. Pacific Northwest Americana: a checklist of books and pamphlets relating to the history of the Pacific Northwest. 2d ed. New York; 1921. 3d ed. revised and extended by I. Mayhew. Portland, OR: Binford and Mort; 1950. 381 p.

Smith, C. W. Special collections in libraries of the Pacific Northwest. Seattle, WA: University of Washington Press; 1927. 20 p.

Smith, C. W. A union list of manuscripts in libraries of the Pacific Northwest, compiled by Charles W. Smith. Seattle, WA: University of Washington Press; 1931. 57 p.

Wagner, H. R. The plains and the Rockies: a bibliography of original narratives of travel and adventure 1800-1865. Revised and extended by Charles L. Camp. San Francisco, CA; 1937. 71 p.

Winther, O. O. A classified bibliography of the periodical literature of the Trans-Mississippi West. Westport, CT: Greenwood Press; 1972. 71 p.

Partial List of Source Material

Journals
Letters
Diaries
Unpublished manuscripts
Mechanic liens
Court cases
Newspaper accounts
Cadastral survey notes
Personal interviews
Photograph collections
County commissioner records
Booming plats

Partial List of Repositories

Libraries: university, city, local
Historical Society museums
County museums
Archives: university, State, Federal
U.S. Army Corps of Engineers
U.S. Department of the Interior, Bureau of Land Management
U.S. Fish and Wildlife Service
U.S. Department of Agriculture, Forest Service
Courthouses: county, State, Federal

APPENDIX 8: RIPARIAN TYPES OF THE UPPER SALMON/MIDDLE FORK SALMON RIVER DRAINAGES, IDAHO

Abbreviation	Type
	Tree-dominated Types
ABLA/CACA h.t.	*Abies lasiocarpa/Calamagrostis canadensis* h.t.
ABLA/STAM h.t.	*Abies lasiocarpa/Streptopus amplexifolius* h.t.
PIEN/EQAR h.t.	*Picea englemannii/Equisetum arvense* h.t.
PICO/VAOC c.t.	*Pinus contorta/Vaccinium occidentale* c.t.
POTRI	*Populus trichocarpa* (incidental communities)
	Shrub-dominated Types
ALIN-COST c.t.	*Alnus incana-Cornus stolonifera* c.t.
ALSI-MEFE	*Alnus sinuata-Menziesia ferruginea* (incidental communities)
ARCA	*Artemisia cana* (incidental communities)
POFR/DAIN c.t.	*Potentilla fruticosa/Danthonia intermedia* c.t.
SALIX/CARO c.t.	*Salix* spp./*Carex rostrata* c.t.
SACO/CASC c.t.	*Salix commutata/Carex scopulorum* c.t.
SADR/CACA c.t.	*Salix drummondiana/Calamagrostis canadensis* c.t.
SAEX	*Salix exigua* (incidental communities)
SAGE/CACA c.t.	*Salix geyeriana/Calamagrostis canadensis* c.t.
SAMY/POPR c.t.	*Salix myrtillifolia/Poa pratensis* c.t.
SAWO/CAMI c.t.	*Salix wolfii/Carex microptera* c.t.
SAWO/SWPE c.t.	*Salix wolfii/Swertia perennis* c.t.
	Herb-dominated Types
AGSC-bar c.t.	*Agrostis scabra*-streambar c.t.
ASIN-FEID c.t.	*Aster integrifolius-Festuca idahoensis* c.t.
CARO c.t.	*Carex rostrata* c.t.
CASI	*Carex simulata* (incidental communities)
DECE c.t.	*Deschampsia caespitosa* c.t.
ELPA c.t.	*Eleocharis pauciflora* c.t.
JUBA c.t.	*Juncus balticus* c.t.
MIPE	*Mitella pentandra* (incidental communities)
POPR c.t.	*Poa pratensis* c.t.

APPENDIX 9: RIPARIAN COMMUNITY TYPES OF EASTERN IDAHO AND WESTERN WYOMING

Abbreviation	Community type
	Tree-dominated Community Types
PICEA/EQAR c.t.	*Picea/Equisetum arvense* c.t.
PICEA/COST c.t.	*Picea/Cornus stolonifera* c.t.
PICEA/CACA c.t.	*Picea/Calamagrostis canadensis* c.t.
PICEA/GATR c.t.	*Picea/Galium triflorum* c.t.
POAN/COST c.t.	*Populus angustifolia/Cornus stolonifera* c.t.
POAN/POPR c.t.	*Populus angustifolia/Poa pratensis* c.t.
	Mixed Shrub-dominated Community Types
ALIN/RIHU c.t.	*Alnus incana/Ribes hudsonianum* c.t.
COST/HELA c.t.	*Cornus stolonifera/Heracleum lanatum* c.t.
COST/GATR c.t.	*Cornus stolonifera/Galium triflorum* c.t.
RHAL c.t.	*Rhamnus alnifolia* c.t.
POFR/DECE c.t.	*Potentilla fruticosa/Deschampsia caespitosa* c.t.
POFR/FEID c.t.	*Potentilla fruticosa/Festuca idahoensis* c.t.
POFR/POPR c.t.	*Potentilla fruticosa/Poa pratensis* c.t.
ARCA/FEID c.t.	*Artemisia cana/Festuca idahoensis* c.t.
ARCA/POPR c.t.	*Artemisia cana/Poa pratensis* c.t.
	***Salix geyeriana*-dominated Community Types**
SAGE/POPA c.t.	*Salix geyeriana/Poa palustris* c.t.
SAGE/CARO c.t.	*Salix geyeriana/Carex rostrata* c.t.
SAGE/CACA c.t.	*Salix geyeriana/Calamagrostis canadensis* c.t.
SAGE/mesic forb c.t.	*Salix geyeriana*/mesic forb c.t.
SAGE/POPR c.t.	*Salix geyeriana/Poa pratensis* c.t.
	***Salix boothii*-dominated Community Types**
SABO/CARO c.t.	*Salix boothii/Carex rostrata* c.t.
SABO/CANE c.t.	*Salix boothii/Carex nebraskensis* c.t.
SABO/CACA c.t.	*Salix boothii/Calamagrostis canadensis* c.t.
SABO/EQAR c.t.	*Salix boothii/Equisetum arvense* c.t.
SABO/POPA c.t.	*Salix boothii/Poa palustris* c.t.
SABO/SMST c.t.	*Salix boothii/Smilacina stellata* c.t.
SABO/POPR c.t.	*Salix boothii/Poa pratensis* c.t.
	***Salix wolfii*-dominated Community Types**
SAWO/CAAQ c.t.	*Salix wolfii/Carex aquatilis* c.t.
SAWO/CARO c.t.	*Salix wolfii/Carex rostrata* c.t.
SAWO/CACA c.t.	*Salix wolfii/Calamagrostis canadensis* c.t.
SAWO/CANE c.t.	*Salix wolfii/Carex nebraskensis* c.t.
SAWO/DECE c.t.	*Salix wolfii/Deschampsia caespitosa* c.t.
SAWO/POPA c.t.	*Salix wolfii/Poa palustris* c.t.
SAWO/mesic forb c.t.	*Salix wolfii*/mesic forb c.t.
	Other *Salix*-dominated Community Types
SAEX/EQAR c.t.	*Salix exigua/Equisetum arvense* c.t.
SAEX/POPR c.t.	*Salix exigua/Poa pratensis* c.t.
SALU c.t.	*Salix lucida* c.t.
SAPL c.t.	*Salix planifolia* c.t.
SAEA c.t.	*Salix eastwoodii* c.t.

(con.)

APPENDIX 9 (Con.)

Abbreviation	Community type
	Graminoid-dominated Community Types
CAMI c.t.	*Carex microptera* c.t.
CASI c.t.	*Carex simulata* c.t.
CARO c.t.	*Carex rostrata* c.t.
CAAQ c.t.	*Carex aquatilis* c.t.
CANE c.t.	*Carex nebraskensis* c.t.
CAREX c.t.	Miscellaneous *Carex* c.t.'s
DECE c.t.	*Deschampsia caespitosa* c.t.
POPA c.t.	*Poa palustris* c.t.
POPR c.t.	*Poa pratensis* c.t.
	Forb-dominated Community Types
VACA c.t.	*Veratrum californicum* c.t.
MECI c.t.	*Mertensia ciliata* c.t.
MFM c.t.	Mesic forb meadow c.t.
	Wetlands
	No c.t.'s differentiated

APPENDIX 10: POOL QUALITY RATING TABLES

Since the appearance of our earlier stream evaluation methodology manual (Platts and others 1983), some refinements have been made in techniques. The chief of these has been modification of the pool quality rating tables to reflect stream size based on stream order (Langbein and Iseri 1960; Strahler 1957). In situations where stream order is not clearly applicable, such as streams that are predominantly spring-fed, order can be assigned on the basis of size using other streams of known order in the area for reference. This appendix contains three pool quality rating tables for streams of orders 1 and 2, 3 through 5, and 6 or greater, respectively.

Table 41—Rating pool quality in streams of order 1 and 2

	Description	Pool rating
1A	Maximum pool diameter is within 10 percent of the average stream width of the study site . . . Go to 2A, 2B	
1B	Maximum pool diameter exceeds the average stream width of the study site by 10 percent or more . . . Go to 3A, 3B, 3C	
1C	Maximum pool diameter is less than the average stream width of the study site by 10 percent or more . . . Go to 4A, 4B, 4C	
2A	Maximum pool depth is less than 1 foot . . . Go to 5A, 5B	
2B	Maximum pool depth is greater than or equal to 1 foot . . . Go to 3A, 3B, 3C	
3A	Maximum pool depth is greater than or equal to 2 feet, regardless of cover conditions, or depth is greater than or equal to 1 foot with abundant fish cover[1]	Rate 5
3B	Maximum pool depth is less than 1 foot with intermediate to abundant cover, or is between 1 and 2 feet and lacks abundant cover	Rate 4
3C	Maximum pool depth is less than 1 foot and fish cover is rated as exposed	Rate 3
4A	Maximum pool depth is greater than or equal to 1 foot with intermediate[2] or better cover	Rate 3
4B	Maximum pool depth is less than 1 foot but fish cover is intermediate or better, or depth is greater than or equal to 1 foot with exposed cover conditions	Rate 2
4C	Maximum pool depth is less than 1 foot and pool cover is rated as exposed[3]	Rate 1
5A	Pool with intermediate to abundant cover	Rate 3
5B	Pool with exposed cover conditions	Rate 2

[1] If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has a fish cover.

[2] If cover is intermediate, the pool has moderate instream cover and one-half of the pool perimeter has fish cover.

[3] If cover is exposed, the pool has poor instream cover and less than one-fourth of the pool perimeter has any fish cover.

Table 42—Rating pool quality in streams of order 3 through 5

Description	Pool rating
1A Maximum pool diameter is within 10 percent of the average stream width of the study site	Go to 2A, 2B
1B Maximum pool diameter exceeds the average stream width of the study site by 10 percent or more	Go to 3A, 3B, 3C
1C Maximum pool diameter is less than the average stream width of the study site by 10 percent or more	Go to 4A, 4B, 4C
2A Maximum pool depth is less than 2 feet	Go to 5A, 5B
2B Maximum pool depth is greater than or equal to 2 feet	Go to 3A, 3B, 3C
3A Maximum pool depth is greater than or equal to 3 feet, regardless of cover conditions, or depth is greater than or equal to 2 feet with abundant fish cover[1]	Rate 5
3B Maximum pool depth is less than 3 feet with intermediate to abundant cover, or is between 2 and 3 feet and lacks abundant cover	Rate 4
3C Maximum pool depth is less than 2 feet and fish cover is rated as exposed	Rate 3
4A Maximum pool depth is greater than or equal to 2 feet with intermediate[2] or better cover	Rate 3
4B Maximum pool depth is less than 2 feet but fish cover is intermediate or better, or depth is greater than or equal to 2 feet with exposed cover conditions	Rate 2
4C Maximum pool depth is less than 2 feet and pool cover is rated as exposed[3]	Rate 1
5A Pool with intermediate to abundant cover	Rate 3
5B Pool with exposed cover conditions	Rate 2

[1] If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has a fish cover.

[2] If cover is intermediate, the pool has moderate instream cover and one-half of the pool perimeter has fish cover.

[3] If cover is exposed, the pool has poor instream cover and less than one-fourth of the pool perimeter has any fish cover.

Table 43—Rating pool quality in streams of order 6 or greater

Description	Pool rating
1A Maximum pool diameter is within 10 percent of the average stream width of the study site	Go to 2A, 2B
1B Maximum pool diameter exceeds the average stream width of the study site by 10 percent or more	Go to 3A, 3B, 3C
1C Maximum pool diameter is less than the average stream width of the study site by 10 percent or more	Go to 4A, 4B, 4C
2A Maximum pool depth is less than 4 feet	Go to 5A, 5B
2B Maximum pool depth is greater than or equal to 4 feet	Go to 3A, 3B, 3C
3A Maximum pool depth is greater than or equal to 6 feet, regardless of cover conditions, is over 4 feet with abundant fish cover[1]	Rate 5
3B Maximum pool depth is less than 6 feet with intermediate to abundant cover between 4 and 6 feet and lacks abundant fish cover	Rate 4
3C Maximum pool depth is less than 4 feet and fish cover is rated as exposed	Rate 3
4A Maximum pool depth is greater than or equal to 4 feet with intermediate[2] or better cover	Rate 3
4B Maximum pool depth is less than 4 feet but fish cover is intermediate or better, or depth is greater than or equal to 4 feet with exposed cover conditions	Rate 2
4C Maximum pool depth is less than 4 feet and pool cover is rated as exposed[3]	Rate 1
5A Pool with intermediate to abundant cover	Rate 3
5B Pool with exposed cover conditions	Rate 2

[1] If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has a fish cover.

[2] If cover is intermediate, the pool has moderate instream cover and one-half of the pool perimeter has fish cover.

[3] If cover is exposed, the pool has poor instream cover and less than one-fourth of the pool perimeter has any fish cover.

U.S. GOVERNMENT PRINTING OFFICE: 1987—773-039/41,036 REGION NO. 8

Platts, William S.; Armour, Carl; Booth, Gordon D.; Bryant, Mason; Bufford, Judith L.; Cuplin, Paul; Jensen, Sherman; Lienkaemper, George W.; Minshall, G. Wayne; Monsen, Stephen B.; Nelson, Rodger L.; Sedell, James R.; Tuhy, Joel S. Methods for evaluating riparian habitats with applications to management. General Technical Report INT-221. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987. 177 p.

This report develops a standard way of measuring and evaluating riparian conditions. These methods will be helpful to those persons documenting, monitoring, predicting, or evaluating riparian, stream, or range conditions, and how this relates to their biotic resources, especially those conditions needed to relate to impacts from land uses.

KEYWORDS: methods, range, riparian, aquatic habitat, fish, streams, inventory, macroinvertebrates

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

CAUTION:
PESTICIDES

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

Clemson University
3 1604 003 837 954

DATE DUE

MAY 1 9 1998
RT/CO APR 14 '98
APR 2 9 1992
Ret'd MAR 2 9 1992
MAY 0 3 1992
JUN 1 1 1992
JUL 2 0 1992
AUG 3 1 1992
Ret'd AUG 2 2 1992
OCT 2 4 1992
RET'D OCT 1 3 1992

DEMCO, INC. 38-2931